The supply of building materials to construction projects in Roman Oxfordshire:
logistics, economics, and social significance

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Abstract

Whilst Roman architecture has long stood as a discrete branch of classical studies, investigated for its artistic merit and cultural importance, the technical details of Roman construction have only recently started to receive considerable attention. This thesis contributes to a growing trend in Roman scholarship, that of the investigation of the processes, materials, and technologies behind the Roman built environment. The most prestigious buildings of the Empire often remain the focus of many of these studies, and so this thesis turns to explore the use of more everyday buildings and building materials, seeking a Romano-British vernacular, and investigating the processes of construction, building material production, and transport.

It is argued, through using theoretical calculations of building material quantities, that even for relatively minor constructions, considerations of building material supply must have represented highly significant economic and logistical investment. To comprehend fully the subject it is asserted that building materials should not be treated, as they often are, as disparate artefacts, divided by substance into stone, ceramic, mortar, metal, etc., but rather they should be considered as related fragments of a building. They require synthetic analysis, through which a far truer understanding of the incredible effort involved in construction in the ancient world can be gained.

The built environment of Roman Oxfordshire, and the Roman building material assemblage from Dorchester on Thames, are used as case studies. Primary analysis of building materials is carried out using an integrated analytical approach, combining thin section petrography with scanning electron microscopy and energy dispersive x-ray analysis. The outcomes of these analyses are interpreted against a background of archaeological and historical evidence for construction and material supply, in both the Roman and later periods, in the region and beyond.

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List of Abbreviations

ADS – Archaeological Data Service

AIP - Archaeological Investigations Project

AMIE - Archives Monuments Information England Database

BGS – British Geological Survey

CBM – Ceramic Building Material

CIL – Corpus Inscriptionum Latinarum

EDX – Electron Dispersive X Ray Analysis

GIS – Geographic Information System

NERC – Natural Environment Research Council

OS – Ordnance Survey

RIB – Roman Inscriptions of Britain

SEM – Scanning Electron Microscope/Microscopy

1. Introduction

Numerous studies of “Roman architecture” have been undertaken, from the Renaissance and Baroque work of the likes of Brunelleschi, Michelangelo, and Palladio, through to the 20th-and 21st-century academic reviews by Boethius, Ward-Perkins, and Sear, amongst others.[1] Building remains are the largest, often most impressive elements of material culture surviving from the period, and the building styles developed under the Romans had a great influence on later architecture across many regions of the world, through the Pre-Romanesque and Romanesque styles, in the Renaissance, and in Neoclassicism. Much has been written on this topic, and there is no need for a detailed survey of the matter here.[2]

However, as will be demonstrated below (Chapters 2.1 and 2.2), studies of Roman architecture are often restrictive in their coverage, focusing on the best-preserved, grandest buildings, and so concerned only with the products of elite investment in construction in the largest cities in the Empire. Thus also the most prestigious building materials and construction techniques are considered in great detail, whilst there is a broad lack of discussion of structures built, used, or lived in by those beneath the top of the social or wealth spectrum.[3] Considering Roman Britain, the degree of applicability of the conclusions of many general works on Roman architecture to the buildings of all but the grandest on that island, the most northerly of Rome’s provinces, is arguable.

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[1] E.g. Blake (1947); (1959); (1973); Lugli (1957); Brown (1961); Boethius (1978); MacDonald (1982); (1986); Ward-Perkins (1988); (1994); Sear (1998); Gros (1996).

[2] E.g. Pevsner (1957); Anderson (2013).

[3] Such structures, built using common and simple building materials and techniques, might be considered not “architectural,” often built without the obvious input of an architect, and thus might be considered “vernacular” buildings. The applicability or not of this architectural theory, of vernacular construction, to “un-architectural” Roman structures will be discussed in more detail in Chapter 7.

1.1. Aims and Research Questions

This research therefore aims to join the now growing movement to readjust focus onto those issues of construction, and to give attention to the more 'ordinary' aspects of building, particularly building materials, and the more 'ordinary' buildings themselves.[4] Regarding materials, much previous work has focused in particular on marble, but this thesis will explicitly examine the 'everyday materials' which must have, by far, dominated the economy of building material production, movement, and use.[5] Stone and ceramic building materials will form the major focus, but consideration will also be given to other important building materials which rarely survive or are rarely identified in the archaeological record, such as timber, thatch, and earth.[6]

The major hypothesis of this study is that despite its seeming mundanity and its relative cheapness per unit, because of the vast quantities that we find in the archaeological record, this material represents a far more significant expenditure of human and material resources than it has been given credit for, and thus the building material 'industry' warrants far more investigation than it currently receives.[7] This thesis will investigate the case for this, exploring various factors from the production process through to the transportation and use of the material. Material from Dorchester on Thames, Oxfordshire, will be used as the primary case study for this investigation. Specific research questions include:

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[4] This 'growing movement' includes the monographs produced by the *Arqueología de la construcción* workshop series: Camporeale *et al.* (2008); (2010); (2012); (2014); DeLaine *et al.* (2016).

[5] For the dominance of marble in studies of Roman stone see Chapter 3.1.4.

[6] Mortar is not considered in detail in this thesis, although the author would advocate strongly for its more frequent inclusion in building studies, and the synthesis of mortar analyses with those of stone, ceramic, and any other building materials.

[7] The word 'industry' is not ideal for application to this subject, but there seems to be little better alternative, and so it will be used in this thesis; connotations linked to industrialisation in pre-modern Europe are not implied through its use, but rather the concept of a 'trade' of building material production and distribution, with some degree of specialisation.

i. What raw materials were chosen by Romano-British building material producers in this region?
ii. What processing actions were undertaken during building material production?
iii. What was the nature and scale of building material demand and production in the region?
iv. How and how far was building material moved?
v. How were building materials used, and what was their role in Romano-British society, culture, and the economy?

The second major aspect of this work is the testing of novel theoretical and scientific approaches to the analysis of these materials. Roman building materials have seen few detailed studies, and comprehensive guidelines for their handling and analysis, including both during excavation and in post-excavation, do not exist. A fundamental proposition is that stone and ceramic building materials, and indeed any other materials used in Roman construction, should be analysed as a cohesive artefact assemblage, rather than being separated by substance and analysed by different experts, leading to disparate and incoherent interrogation of the materials. In order to maximise the insight we are able to gain into Roman construction from building materials, detailed, scientific, and synthetic analyses are needed, applied on a regular basis.

1.2. Spatial Scope

1.2.1. Finding Boundaries

Defining the limits of any study is difficult, particularly one concerned in part with connectivity, as that connectivity has no real limit: there will have been routeways, people, and things travelling beyond any boundary set. Several options exist for the creation of a study area.

To use a topographically determined study area was one possibility, and in this region a study area based on the watershed of the Upper Thames could have been suitable. This is a spatial definition that has been used multiple times in past studies of this part of Roman Britain, useful on a number of counts.[8] There exists a certain degree of consistency in topographic and geological features within this region, dominated by open clay downland, with limestone hills and chalk hills forming the northern and southern margins respectively. These two uplands also confine sight-lines within the valley, something which perhaps had an impact on ancient conceptions of place. The River Thames and its tributaries, for some part of their courses, acted as important transport and communications routes, and controlled movement, directing road-traffic towards nodal crossing points. The river has acted as a boundary at various points in history, the Thames and the Cherwell putatively dividing "tribal" groups in the late Iron Age, the Thames dividing the kingdoms of Wessex and Mercia in the early medieval period, and as recently as 1974 the Upper Thames formed a boundary between the counties of Berkshire and Oxfordshire.[9]

However, topographically or geographically determined definitions might be considered flawed. In the first place we cannot perfectly reconstruct the past landscape, nor

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[8] E.g. Benson and Miles (1974); Booth *et al.* (2007).

[9] Lambrick (1998); Allen (2000) 17-32; Booth *et al.* (2007) 8.

individuals' interactions with it. For example, the modern course of the River Thames has been heavily influenced by medieval and post-medieval canalisation, weirs, and locks; it has become very difficult to understand the course, and importantly the depth and character, of the Upper Thames in the Roman period (*cf* Chapter 6.2.3). Whilst it is possible on the modern river to travel by small boat as far upstream as Lechlade in Gloucestershire, good evidence for significant use of the river this far upstream is lacking from the Roman period.[10] Woodland coverage in the region is another factor which is very difficult to reconstruct, the modern landscape having been so altered by the development of farming techniques, enclosure acts, and constantly changing land-uses (*cf* Chapter 5.4.2.2.).[11]

It is of course plain that human actions are not solely influenced by the topography within which they live, but by countless other factors, many of which are far harder to reconstruct for past societies than topographical or geological features; these include for example cultural, economic, societal, kin, and ritual influences. The problems of a purely geographically focused study are demonstrated by the lines of the Roman roads in this region: for the road builders at least, the valley had little impact on their intentions, Akeman Street largely ignoring the contours of the Cotswold Hills for much of its route.[12] It is certain that, with the exploration of Romano-British trade networks central to the aims of this thesis, people and materials will have regularly travelled beyond the limits of the valley, and as such its use as a solid boundary for research is unsuitable.

Using a modern political boundary, the borders of the county of Oxfordshire, to delimit the study, offers an alternative possibility. Using a modern boundary helps to look beyond possible ancient conceptions of a region, and could be seen as a more random sample of

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[10] Henig and Booth (2000) 51; Booth (2007) 313.

[11] *Cf.* Tompkins and Malone (2017).

[12] Margary (1973); Copeland (2009); *cf.* Davies (1998) on the planning of Roman roads in Britain.

the landscape. This definition is certainly useful for research purposes, tying into modern systems for recording and working on ancient landscapes, with many databases using county as the primary spatial query, and resources such as the Historic Environment Record divided and managed by county. However, to see the modern county boundary as entirely removed from the influence of ancient control of space would be naive: county boundaries are often based on those of parishes, which in turn may be over a thousand years old, and might themselves have been based on early medieval charter boundaries, with Roman landscape features such as roads or settlements primary influences on their design. Further, the fact that all of the major towns in this part of Roman-Britain lie outside of the county of Oxfordshire severely limits any study confining itself to looking solely within that area. Some of the major sources of influence, in terms of population centres, market centres, and centres of consumption, would be put beyond the consideration of the research, with the *municipium* of Verulamium (St Albans) in Hertfordshire, and the *civitas* capital of Corinium (Cirencester) in Gloucestershire, and of Calleva (Silchester) in Hampshire.

With these approaches individually proving unsatisfactory a combination of both is necessary (Fig. 1.1). For the purposes of this study the primary factor is a focus on the Roman small town of Dorchester on Thames, as the source location for the main assemblage of case study material. In order to explore the landscape in which it sits, the county boundary of Oxfordshire is used as the limit for exploring broader landscape questions, whilst when considering the specific networks in which Dorchester was involved, the net will be cast beyond those boundaries to include the major towns in the vicinity.

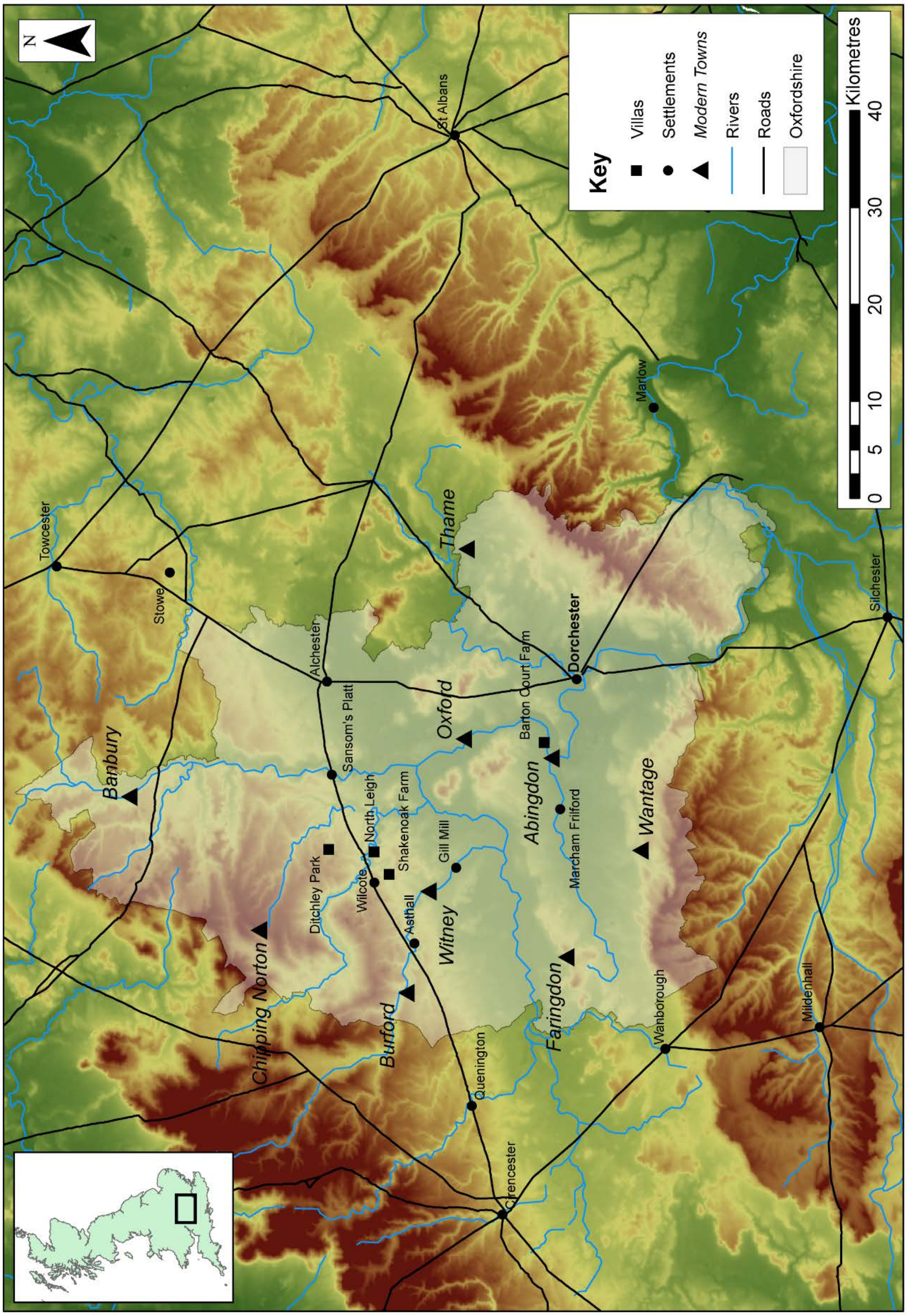

Figure 1. 1: A map of the study area, with topography, major rivers, Roman roads, Roman settlements mentioned in the text, and the modern county boundary of Oxfordshire and some modern settlements marked. Terrain data © OS (2017).

1.2.2. Natural Features of the Study Area

The modern County of Oxfordshire covers 2605 km^2 of land in southern central England. The landscape of the county is defined by three major features. Firstly, in the north of the county sits a string of hills, running roughly south west to north east, called the Cotswold Hills. Secondly, another area of high ground runs along the southern edge of the county, roughly west to east, the North Wessex Downs, which become the Chiltern Hills in the east of the county. And thirdly, the River Thames and its tributaries score the landscape: Oxfordshire makes up a significant portion of what is known as the Upper Thames Valley, the river running eastwards from its source in Gloucestershire, to Oxford, from where it diverts to the south, making its way towards Reading, and dividing the North Wessex Downs from the Chiltern Hills in the narrow "Goring Gap."

The precise geology of the study area will be described in more detail below (Chapter 3.2.4, Fig. 3.3, Catalogue 1), but in brief, the county sees a transition southwards from the Middle and Late Jurassic limestone uplands of the Cotswold Hills, down onto a succession of late Jurassic and Early Cretaceous clays, divided by minor outcrops of the Corallian and Portland limestones and sandstones and Lower and Upper Greensands, before the chalks of the North Wessex Downs rise to the south.[13] In the direct vicinity of the Thames and its major tributaries lie gravel terraces, laid down in the Pleistocene.

1.2.3. Roman Features of the Study Area

Oxfordshire has seen substantial levels of archaeological investigation, showing the long history of human occupation in this region. The freely-draining gravel river terraces, widely cultivated, offer ideal conditions for producing crop marks, and the economic value of the gravels themselves fuels significant developer-funded archaeology as a pre-cursor

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[13] Arkell (1947); Powell (2005).

to their extraction.[14] Numerous Roman sites, including towns, rural settlements, villas, and farmsteads, have been discovered and studied individually.[15] Syntheses of the Roman settlement patterns together with analyses of the social and economic character of the region have been created, showing a picture of a dynamic Roman landscape of arable and pastoral farming and with villas lining the steep valleys and ridges of the Cotswolds.[16]

Three main Roman roads cross the county: Akeman Street (Margary 16), which runs westwards from Verulamium (St Albans) to Corinium (Cirencester), cutting through the county along the southern flank of the Cotswolds; an unnamed road (Margary 160) running almost due south to north through the county, coming up from Calleva (Silchester), through the Goring Gap, to head up to meet Watling Street at Lactodurum (Towcester) in Northamptonshire; and Ermin Street (Margary 41) running south east to north west over the North Wessex Downs from Calleva to Corinium.[17] As noted above, there were no major Roman towns within the confines of Oxfordshire, but there were a number of sites which might be termed "small towns," "agglomérations secondaires," or perhaps *vici*; these are terms which have provoked significant argument over their meaning and application, but are here used to categorise the agglomerated settlements of Roman Oxfordshire above the level of villas or farmsteads.[18]

The Oxford Roman pottery industry, known from a cluster of kilns along the north – south Silchester – Towcester road (Margary 160) between Dorchester and east Oxford, was highly significant, particularly in the third and fourth centuries, when its products were exported all across Roman-Britain, particularly to London and into the Severn Valley.[19]

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[14] Benson and Miles (1974).

[15] *Cf.* Booth *et al.* (2007) for the most recent synthesis and bibliography.

[16] Henig and Booth (2000); Booth *et al.* (2007).

[17] Margary (1973) 129-167 and Fig. 5.

[18] On "small towns:" Todd (1970); Wacher (1975); Burnham (1986); Burnham and Wacher (1990); Leveau (1993); Jacques (1991); Brunella (1994); Brown (1995); Redde (1995); Booth (1998); Woolf (1998); Garmy (2012) for a useful summary.

[19] Young (1977) 355 ff; Booth *et al.* (2007) 308-311.

As mentioned this study uses as its primary case study material from the Roman small town at Dorchester on Thames.[20] The subject of ongoing excavations run by the University of Oxford and Oxford Archaeology, Dorchester sits in South Oxfordshire at the confluence of the Rivers Thames and Thame, and on the main Roman road running from Silchester to Towcester. The Roman town was founded in the second half of the 1st century AD, perhaps in the vicinity of a conquest period fort, and also located just a few hundred metres north of the large middle- and late-Iron Age settlement known as the Dyke Hills Encampment.[21] The town saw the construction of a rectangular earth rampart, enclosing c. 6 hectares, in the first half of the 2nd century AD, which was converted into a stone rampart in the late 3rd-century AD. An extra-mural settlement is known along the road running south east from the town, just the far side of the River Thame.[22] Some elements of the internal organisation of the town were shown by Frere's excavations of the 1960s, a picture being expanded upon by the current University of Oxford and Oxford Archaeology excavations: the main road through the centre of the town has been identified, along with perpendicular minor roads, and several stone buildings and numerous post-built structures.[23] Occupation seemingly continued right up to and beyond the end of the Roman period into the 5th century, with two Saxon "sunken feature buildings" having been excavated, and burials have been excavated which were inserted into the Dyke Hills, found with elaborate Germanic metalwork grave goods often associated with 5th-century "foederati" mercenaries.[24] The site thus provides not just a case study of a Romano-British small town, a settlement type which certainly needs more investigation in order to

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[20] On Dorchester: Stevens and Keeney (1935); Atkinson, Piggott and Sandars (1951); Frere (1962), (1984); Henig and Booth (2000) 58-63; Booth *et al.* (2007) 70-73; Morrison (2009).
[21] Booth *et al.* (2007) 70; *cf.* Allen (2000) 22.
[22] Ainslie (2011).
[23] Booth (2008-2013).
[24] Booth *et al.* (2007) 70-73; (2014).

understand better the organisation and economics of these sites, but also an example of a settlement which spans the entirety of the Romano-British period.

The other major settlement site within the county borders is that of Alchester. Its origins were as a conquest period fort, dendrochronological analysis of preserved timber from the fort annexe gate posts dating the structure to the autumn of AD 44 or early AD 45.[25] The find of the tombstone of Lucius Valerius Geminus, reused in the gates of the civilian town, and estimated to date to no later than the AD 60s, forms the basis of Sauer's argument that the fort was a base for Vespasian and the 2nd Legion during the conquest.[26] Following this early period the fort site developed into a civilian settlement. Alchester, like Dorchester, gained an earth rampart in the second half of the 2nd century, with an associated stone wall: Young claims that this was contemporary with the earth bank, but Sauer argues for the more usual sequence seen in southern Britain of a stone wall being added in the later 3rd century, as at Dorchester.[27] These walls enclose an area of c. 10.5 hectares, with evidence from crop marks and excavation showing a regular grid plan, many buildings, including three possible temples, as well as significant extra-mural settlement, making the total inhabited area possibly as much as 40 or 45 ha.[28] Stone footed as well as post-built structures have been identified both within the town and in the extra mural settlement.[29]

Beneath these towns in the hierarchy of Oxfordshire's Roman settlements were the smaller agglomerated sites, sometimes termed roadside settlements, nucleated rural settlements, or villages. These include Sansom's Platt, Wilcote, and Asthall along Akeman Street near to the road crossings of the Glyme, Evenlode, and Windrush Rivers respectively.[30] Further

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[25] Sauer (2002)
[26] Sauer (2005a) 207-10; (2005b); (2007).
[27] Young (1975) 154; Sauer (2007) 12-13.
[28] Rowley (1975) 118; Henig and Booth (2000) 52.
[29] Foster (1989); Henig and Booth (2000); Booth *et al.* (2002); Sauer (2007).
[30] Brodribb (1968); (2005); Hands (1993); (1998); (2004); Booth (1997); Winton (2001); Booth *et al.* (2007) 38ff.

important examples include Gill Mill, in the lower Windrush valley, Swalcliffe Lea in the north of the county adjacent to the Iron Age hillfort at Madmarston Hill, and the temple site at Marcham / Frilford.[31] Beneath these sites in the hierarchy were myriad rural settlements, characterised as small villages, farmsteads, and villas. The majority of the Roman sites identified across the county fall into these categories, including for example the major villas at Shakenoak Farm, North Leigh, and Ditchley, the large farmstead at Barton Court Farm, and many smaller sites such as the domestic and agricultural buildings found at Denchworth Road, Wantage.[32]

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[31] Gill Mill: Booth *et al.* (forthcoming); Swalcliffe Lea: Webster (1975) 59-61; Henig and Booth (2000) 68; Marcham Frilford: Kamash *et al.* (2010);

[32] North Leigh: Ellis *et al.* (1999); Wilson (2004). Ditchley: Raleigh Radford (1936); Booth (1999b). Barton Court Farm: Miles (1986). Denchworth Road, Wantage: Barber and Holbrook (2001). *Cf.* the *Rural Settlement of Roman Britain* project, URL = http://archaeologydataservice.ac.uk/archives/view/romangl/ (Accessed 18/08/17).

1.3. Thesis Outline

The thesis begins with an overview of what we know of Roman buildings and construction in Britain, and specifically in the study area (Chapter 2), before discussing building materials in particular, and their promise as artefacts holding significant value to archaeologists of Roman societies and economies (Chapter 3). The importance, and difficulty, of using geological data is also examined. The scientific approaches available for studying building materials are then considered, followed by the methodology and results of the scientific analyses carried out as part of this research (Chapter 4). This chapter is concluded with an evaluation of the methodology used, and suggestions are made for future approaches to excavating, archiving, and analysing building materials. Chapters 5 and 6 investigate in greater detail the nature of the production and trade of building materials, utilising the theoretical model of the *chaîne opératoire*, exploring what can be learnt from the analyses of material from Dorchester carried out in Chapter 4. Chapter 5 investigates the early stages of the *chaîne*, including the selection and extraction of raw materials and their processing, utilising landscape-based approaches and evidence from later periods to aid our understanding of the Roman industry. Chapter 6 looks at the trade in building materials, with a discussion of transport in the Roman world, highlighting the fact that building materials are needed in such large quantities that traditional views of Roman transportation need to be modified. Landscape approaches are again used to explore the movement of building materials, and the routeways in the study area which might have been utilised for their distribution are discussed in detail. Chapter 7, the conclusion, summarises the major results of this research, including outcomes related to the nature and character of Roman building material production and distribution, a possible connection between building material production and agricultural landscapes and economies, and a consideration of the use of these materials within the theoretical frameworks of identity and vernacular architecture.

2. Construction in Roman Britain

"Their houses, which are large and dome-shaped, they make of planks and wicker, throwing up over them quantities of thatch" – Strabo, *Geographica* IV.4.3.

As noted in the Introduction, the focus of much work on Roman architecture and construction is biased towards the grandest buildings and most prestigious building materials. Regardless of how seriously we take the quote above from Strabo, writing about the Gauls explicitly up to "the present time" in the late 1st century BC, and how true it might hold for Britain in the middle and later imperial periods, it reminds us that we need to be careful of extrapolating our understanding of construction in the more wealthy and longer urbanised core of the Mediterranean to the north western outskirts of the Empire. This chapter will begin by investigating the neglect of lower status, perhaps 'vernacular' building styles of the Empire and in Britain. This is followed by a survey of the architectural techniques seen in the province of Britannia, considering the general quality of these data and the problems we face in collecting and analysing them. The ultimate aim of this exercise is to gain an overview of the character of the architecture of the region. Hypothetical reconstructions of regional buildings will be discussed, with the aim of calculating broad estimates for the scales of various building materials needed.

2.1. Building Bias across the Empire

As referred to above, historically, discussion of Roman building has tended to focus on *architecture*; that is the physical manifestation of building design, decoration, and function, rather than the wider subject of *construction*, the processes, technology, materials, and logistics involved in the creation of the building. More specifically, considering urban sites, the architecture of civic and public buildings such as theatres, temples, baths, and palaces, and large domestic buildings, such as the wealthy *domus* of Pompeii, take the focus. With regard to rural sites, elite villas have dominated research. This academic focus can be demonstrated by a survey of the keyword-classified *Archäologische Bibliographie*, the former Subject Catalogue of the German Archaeological Institute in Rome (the DAI).[33] Using the keyword search, the frequency of study of different building types can be roughly gauged by the number of records tagged with a particular keyword. The results of this survey are shown in Table 2.1.

	Building category	**Number of records**
Urban sphere	Temples	2088
	Baths	1459
	Theatres and odeia	1067
	Industrial buildings and shops	598
	Palaces	470
	Amphitheatres	397
	Basilicas	190
	Inns	143
	Store buildings	136
	Circus buildings	105
Rural sphere	Villas	2268
	Farmsteads and rural buildings	577
Other	Fortresses	1552
	Unclassified buildings	265

Table 2. 1: A survey of number of records by bibliographic keyword in the DAI Archäologische Bibliographie.

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[33] Accessed through *Projekt Dyabola*, URL = http://www.dyabola.de/en/indexfrm.htm?page=http://www.dyabola.de/ (accessed 15/10/17).

This survey is patently not a complete representation of the academic reality: the *Archäologische Bibliographie* considers monographs, articles from published journals, and collected editions, but only from 1956 onwards, and with German, Italian, French, and English language publications much more strongly represented than other languages. These data are potentially flawed by reliance on the precision of the somewhat idiosyncratic keyword system (distinguishing between a "villa" and a "farmstead," for example, without explanation), and the database makes no distinction by keyword between upper class and lower class urban housing, hence it was omitted from the table. Despite these caveats however, these data give a good suggestion of the bias towards public buildings such as temples, baths, entertainment buildings, and villas – buildings probably built with the assistance of architects, or at least with architectural aspiration – over the more mundane structures of shops, industrial buildings, stores, and smaller rural farmsteads, despite the fact that all of these must surely have been far more numerous in the Roman world. "Fortresses" are included in this survey too, demonstrating the focus given to military structures, and the importance of the Roman army more generally in modern classical scholarship.

The patrons of all those grander buildings lie towards the upper ends of the spectra of wealth and social class in the Roman world, and the buildings exist as overt statements of these facts, consciously coded with a language of display, competition, and prestige. An academic focus on those building types is in part due to their more frequent survival in the archaeological record: these structures are often larger, are often well constructed using durable materials, and, often being more architecturally elaborate, may have had a better chance of preservation through subsequent eras, or in the case of villas, often exist outside areas of significant later development. The more prestigious materials used, the architectural styles that have persisted as fashionable to this day, and the richer contents and decoration of the buildings have drawn attention from antiquarians and modern archaeologists alike.

This stands in contrast to lower status buildings, for example simple dwellings, shops, or workshops. These are structures which might have commonly been built in materials such as wood, earth, and thatch, materials that often do not survive well archaeologically, and their function may be far less clear, precluding keyword classification. These buildings lack the architectural elaboration or scale that would have helped their survival, and are relatively ephemeral within the landscape, easily destroyed by human agency, or simply through natural processes over time. They are much less easy to study, and might be seen as less interesting, warranting less academic discussion.

2.2. Building Bias in Britain

A brief survey of the journal *Britannia* (containing articles on Roman Britain, with some content relating to the Iron Age or early medieval periods) offers an interesting comparison, and reveals a somewhat different picture, reflecting something of a divergence between British scholarly themes and those shown in the DAI *Bibliographie* (Table 2.2*)*.

	Building Category	**Number of records**
Urban Sphere	Industrial buildings	26
	Temples	14
	Bathhouses	11
	Houses	6
	Amphitheatres	5
	Forums	5
	Basilicas	3
	Commercial buildings	3
	Theatres	3
	Inns	2
	Circuses	1
	Granaries	1
Rural Sphere	Villas	45
	Farmsteads	7
Military Sphere	Forts	69

Table 2. 2: A survey of number of records by bibliographic keyword in the Journal Britannia.

It is acknowledged that there are again problems with this survey and that it does not necessarily offer a full or precise mirror for the coverage of Romano-British scholarship as a whole. Nor can the data be directly compared with the DAI *Archäologische Bibliographie* survey, due to methodological differences in their creation and their respective sample sizes; *Britannia* is only one journal of many in which the excavation of Romano-British buildings might be reported. Nonetheless, these data show some interesting patterns, some consistent with those seen in the *Archäologische Bibliographie* survey, and some divergent. Urban civic and public buildings appear much less frequently in the titles of *Britannia* articles compared with their frequency in the former survey. It is suggested that this is on account of the different nature of Romano-British built environments compared with those commonly studied elsewhere in the Roman Empire: far fewer monumental urban centres with comparably elaborate, durable, functionally recognisable public buildings, often the product of the euergetic culture in Italy, North Africa, and the eastern half of the Roman Empire, have been excavated in this country, most probably because that culture did not exist in Britain to the same degree, and far fewer of those buildings were ever built. The *Britannia* survey shows something of a predominance of productive buildings. This might in some way reflect the archaeological visibility of certain 'industries,' notably metal work and pottery production, making them a target for publication over urban buildings which have no clear function.

Villas, just as in the first survey, dominate the journal. It seems probable that many of the same reasons outlined above which explain their predominance in German, Italian, and French literature apply equally to Britain. So too temples and bathhouses remain high on the list, being archaeologically relatively durable, visible, and being attractive for study in offering both architectural interest as well as social and cultural discussion.

Finally, military structures were included in the survey because of their predominance in the journal, just as they were well-represented in the *Archäologische Bibliographie* survey. Their high frequency here is understandable, military presence having been significant in

Roman Britain, and it has formed an important focus of research for scholars of the region. It is recognised that a “fort” was a large entity, often covering several hectares and within which multiple other structures would stand, and it thus cannot form a fair direct comparison with the other keywords. However, it is useful in showing a strong theme in Romano-British scholarship.

2.3. Romano-British Architecture

Several good syntheses exist of archaeological evidence for Romano-British architecture in its own right. Ward's *Romano-British buildings and earthworks* is now out of date, but much of his treatment of the subject is sound, for the evidence that was available at the time.[34] Todd's collection of essays on Romano-British villas is important, including regional studies, some focus on architecture, and, importantly, the positioning of British villa culture in the context of patterns elsewhere in Western Europe, whilst Smith's work considering buildings plans, and the social organisation and function within British, French, and German villas adds further excellent material.[35] Johnson's 1996 edited volume, *Architecture in Roman Britain*, collects papers covering diverse subjects such as villas, military sites, courtyard houses, and external decorative styles.[36] Of particular interest are two papers on the unusual survival of gable wall collapses, at Redlands Farm, Northamptonshire, and at Meonstoke, Hampshire, giving primary evidence for the construction of complete walls from foundations to eaves, and demonstrating the existence and design of upper storeys in Romano-British buildings.[37] However the volume does not include papers focused on other less "prestigious" building media or types, such as post-built structures, or structures that might be identified as workshops, lower status houses, or stores. The only exceptions to this are the brief analysis of the military stone *horrea* at Birdoswald and the short discussion of "circular houses" and the potential mill building at Stanwick, Northamptonshire.[38]

Another work of significance is Perring's excellent *The Roman House in Britain*.[39] This work explores the history of Romano-British houses (related both to Iron Age antecedents

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[34] Ward (1911).
[35] Todd (1978a); (1978b); Smith (1963); (1997).
[36] Johnson (1996).
[37] Keevill (1996); King (1996).
[38] Wilmott (1996) 98 ff.; Neal (1996) 42.
[39] Perring (2002).

in Britain and wider trends in Italy and France during the Roman period), their construction, and their function within Romano-British society. Perring's familiarity with the wooden construction techniques evidenced by preserved water-logged timbers from London is a notable strength, building also on the excellent contribution to the subject by Goodburn.[40]

One other key work, although not explicitly concerned with British evidence, is Adam's *Roman Building*, which gives a broad overview of many of the building techniques and styles used by the Romans; the book's heavy emphasis on evidence from Italy, and to a lesser extent France, must however be remembered, leading to a focus on masonry construction, and less on that in timber or earth.[41]

Beyond these books, much of the work on architecture in Roman Britain is confined to smaller or individual studies and excavation reports, and the description of building remains within these is often disappointing, lacking detailed accounts of building remains, construction techniques, and materials.

What follows is an attempt to draw together key threads of evidence from across Britain, and on occasion the wider Empire, to suggest the main constructional techniques which would have been used in Roman Britain, and thus the choices available to those planning to build.

2.3.1. Building Techniques and Materials

Using the above publications and other reports of Roman buildings in Britain, the techniques and materials used can broadly be categorised, to put together a picture of the available choices. This categorisation is based firstly on the materials used, being the most readily assessed characteristic of any excavated remains of a Roman building, due to the

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[40] Goodburn (1991).
[41] Adam (1994), esp. 86 ff.

often poor state of preservation of most Romano-British buildings. From this initial categorisation judgements about construction techniques can often also be made. Beyond these two characteristics, however, we are usually very limited in our evidence for the construction of upper floors, decoration, the occurrence and fashion of openings such as doors and windows, and often the basic building functions.

The categorisation system that follows necessarily takes a somewhat generalised approach, compartmentalising construction techniques into discrete groups. It is not claimed that all Roman buildings must fit one or other category only: it should be remembered that buildings are highly complex artefacts. They might include multiple different building techniques throughout, and what we find archaeologically, often only foundations, will not always be a sufficient guide to the construction techniques of the superstructure. Another important caveat is that a building was not a fixed, immutable entity, but was an evolving quantity, which might change rapidly over the course of a short space of time through extension or renovation.

Equally there might be numerous variations within these techniques in terms of the precise materials or the precise ways that they were used, down to the individual skills and actions of the builder and the materials they have to hand, and also as a result of the choices of the patron. This system of categorisation does however give a broad overview of what the evidence tells us about how Romano-British buildings were created, and it will assist in our aims of further exploring the logistics of construction projects.

2.3.2. Categorising Construction Techniques

The construction techniques which might have been chosen for construction in Roman Britain, broadly grouped, are as follows:

- Earth-based mass-walling systems (e.g. cob, pisé de terre, mud-brick).
- Earth-fast footings for timber principal posts or studs, with assorted infill wall types.
- Timber baseplate footing, with timber frame construction and assorted infill wall types.
- Masonry footing, with assorted superstructure types.

An account will be given of each structural method, noting the techniques and materials used. This will include a short discussion of the origins of the technique and the technologies, tools, and skill involved. Possible advantages or problems that might have affected the choice of that building technique will also be discussed. This will be followed by a note on the longevity and decay of structures built using each technique, the evidence that might conceivably remain in the archaeological record of these buildings, and examples of their use in the Roman world, particularly Britain. This will be followed by a short discussion of roofing techniques.

2.3.2.1. Earth-Based Mass-Walling Systems

We begin with perhaps one of the least well-studied construction materials and techniques of the Roman period: earth-based mass-walling systems. This construction method is highly important, the raw material being so abundant and the techniques relatively simple; today it is estimated that over one third of the world's population live in earth buildings, and it is clear that the prevalence of use of this material, on account of its many advantages, extends back into historic and prehistoric periods.[42] Well-made walls of

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[42] Reeves, Sims and Cripps (2006) 387.

this type can stand for several centuries, even in regions where climatic conditions are particularly adverse, as evidenced by surviving medieval examples in Britain.[43] However, in longer timescales this material does not survive well, and once it starts to decay, allowing moisture to ingress, water and frost damage accelerate and the wall can be reduced to very scant remains within a short period. Thus only a handful of sites with substantial earth construction remains survive from the Roman period in Britain.

There are four main techniques considered here: cob, earth mortar, pisé de terre, and mud brick. Common to all of these techniques are the ease of raw material acquisition, the excellent thermal properties of walls made from earth, and the difficulties of recognising the use of the material archaeologically. Some of the best work on earth construction has taken place in France, in particular through the three *Échanges transdisciplinaires sur les constructions en terre* workshops, published in three volumes focussing respectively on formed, cut or moulded earth, pisé and cob, and mud brick.[44] A useful short summary of the key distinctions between the major earth construction techniques has been published online by Perello.[45]

Cob walling

Cob walling, known as *bauge* in French, is created by the layering of wet earth and organic material (e.g. wheat straw or chaff), to gradually build up a solid mass wall.[46] The precise recipe for the raw materials can vary substantially and still yield a functional finished product, but mixtures creating a stronger, more durable wall might be made from soils with not too high a clay content (which, whilst facilitating a stronger binding, also increases shrinkage, leading to cracking and thus accelerated damage), and a small

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[43] Hurd and Gourley (2000).

[44] De Chazelles and Klein (2003); Guillaud *et al.* (2007); De Chazelles *et al.* (2011).

[45] Perello (2015) URL = http://archeorient.hypotheses.org/4562 (accessed 23/1/2017).

[46] Keefe and Child (2000) 37.

proportion of gravel inclusions.[47] The earth and straw might be puddled with water and trampled before use to combine them, or they might be laid in alternating layers during construction.[48] Each successive layer is laid once the preceding layer has dried enough to support the weight of the next, the material packed together tightly (again possibly by trampling on the wall).[49] The more thoroughly the previous lift has been allowed to dry before adding the next, the less prone to cracking or settling the wall will be.[50] The edges of the wall might be made straight at the end of the process with a cutting tool like an adze, a small mattock, or a paring iron.[51] Walls of this type tend to be of at least 400 to 600 mm thick, their strength coming from their massive nature (although, as seen in later periods, with highly optimised recipes for the cob walls as thin as 200 mm can be constructed to a considerable height).[52]

The construction of cob requires relatively little skill (compared to masonry construction, for example), and is also relatively labour un-intensive and can be undertaken rapidly; halts in work on a section of wall would be needed to let the previous lift dry before adding the next, but the workers could move onto the adjacent section of wall whilst this was happening. Early 19th-century accounts describe how whole neighbourhoods would come together to build the walls of a cob house in just a few hours.[53] The technique provides strong walls, capable of carrying multiple stories and substantial roofs, is made from cheap, easily available materials extracted in the vicinity of the building site, and the end-product is a material with high thermal mass, therefore efficiently insulating the interior

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[47] Keefe (2012) 81.

[48] Keefe and Child (2000) 37.

[49] Keefe and Child (2000) 37.

[50] Keefe (2012) 81.

[51] Keefe (2012) 81.

[52] On thickness: Messenger (2000) 8; Keefe and Child (2000) 35. 'Wychert' walling from the Midlands, making use of naturally lime rich soils, is very strong and sometimes only c. 20 cm thick: Hurd (2000) 15.

[53] Walker, McGregor, and Little (1996) 46-47: letters between the Earl of Mansfield and his agents on his estates in Dumfriesshire and Perthshire, 1810-1817.

and retaining heat; the material is also flexible in terms of constructional uses, and is easily and cheaply repaired.[54]

As mentioned, such walls can stand for several hundred years if properly maintained. Key to this is ensuring that water does not enter the matrix, through penetration from above, from below, or from the sides. Thus an effective roof is needed, often of stone or thatch; standing on a masonry socle, or at least a gravel foundation, is desirable; and some form of weatherproofing, such as lime rendering, and a large roof over-hang, significantly increase the longevity of the wall. If water does ingress a combination of the water's movement and freeze-thaw processes bring about the damage to the wall. Rodent or other burrowing animals and insects can also be a problem. Medieval examples of cob-built structures in Britain survive certainly from the 15th century AD, and probably earlier, demonstrating that if properly maintained these structures can stand for over 600 years.[55]

When intact walls do not survive in the archaeological record from the Roman period the indication of their past presence will be the distinction between the overlying deposit and the material of the wall, possibly crumbled into a slump of earth; often collapsed cob may be distinguishable on account of higher clay, sand, or gravel content than naturally occurring deposits, with these components having been added by the builder to improve the properties of the cob: this distinction may be very subtle, requiring careful excavation by an experienced archaeologist familiar with the site's soils. Indeed there may not be a clear distinction, rendering identification of the past presence of a cob wall impossible. Distinction between cob and other earth-based construction techniques will be discussed further below. The stone socle, if originally present as a base for the cob, is obviously more resistant to decay, but may have been robbed (perhaps leaving a robbing or construction cut as evidence of its presence). Multiple construction techniques may however have made

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[54] Collet *et al.* (2006); Forster *et al.* (2008); Morel *et al.* (2012)

[55] E.g. Devon Historic Buildings Trust (1992).

use of a stone socle, as will be shown below, and as such, on its own, the socle does not necessarily permit the determination of the technique from which the superstructure was made. It might tentatively be associated with a cob wall if no indications can be found of grooves for a timber frame superstructure or for the placement of the formwork for pisé de terre construction, discussed more below.

The origins of cob are unclear, primarily perhaps because of the difficulties of identifying the technique archaeologically. Given the relative simplicity of the technique and wide availability of materials, it is likely to be extremely ancient; one might even assume that it pre-dates the earliest mud-brick constructions, seen in the Neolithic in Mesopotamia and the Levant.[56] The earliest appearances of cob in Britain are also unclear. Perring notes that there was a pre-Roman tradition of cob building at Godmanchester, which continues into the Roman period, and Phillips notes a tradition in the Fens.[57] Perring also suggests a predominance of this technique during the Roman period in regions dominated by "British" populations, such as the south west, implying a link with pre-Roman traditions rather than a novel imported Roman technique.[58] Pre-Roman origins are certainly believable, perhaps arising either through independent development within Britain, given the simplicity of the technology, or arriving through cultural transmission from Iron Age France, where the technique is suggested from the 2nd century BC (with possible Greek or Roman influence).[59]

The technique was almost certainly used broadly across the Roman Empire, and, for example has been firmly identified and discussed at Lattes (Herault, France).[60] Evidence from Britain is relatively scant, but it has been noted at both rural and urban sites.[61]

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[56] De Chazelles (2011) 154.
[57] Phillips (1970); Green (1975); Perring (2002).
[58] Perring (2002) 105.
[59] De Chazelles (1990)
[60] De Chazelles and Roux (1999); Roux (2003); Roux and Cammas (2010).
[61] E.g. Field (1965); Perring (2002) 105.

Interestingly for this thesis one of the places cob construction has been postulated is at Dorchester on Thames, Rowley and Brown noting that the most common construction technique uncovered in their excavations in the town “appears to have been cob and/or timber walls sitting on rough stone sills.”[62] This identification of cob is therefore based predominantly on the discovery of stone socles with no clear indication of the superstructure technique, rather than any positive evidence for the technique, and they acknowledge that the suggestion is in part also based on the fact that the technique is used in a few property boundary walls in the town standing today.[63] Of course with just the stone socles, by their own admission heavily robbed, remaining, and with no further evidence, this identification should not necessarily be treated as sound.

Earth Mortar Construction

A different technique, likened by Russell and Fentress more to cob construction than pisé de terre, but which bears significant distinctions in methodology, is the laying of earth between two solid wall faces.[64] It seems to me that perhaps this technique, distinct from both cob and pisé de terre, should actually be recognised by its own appellation, as earth mortar construction.

As in cob walling this earth is sometimes utilised whilst wet and plastic, and is puddled with organic temper; the two solid faces serve as a sort of formwork for the technique. Early examples of this technique in North Africa include the city walls at Kerkouane, soil packed between the two stone faces, and at Carthage on the Byrsa, soil deposited between roughly fired bricks.[65] At Roman Lattes soil is used as a core between mud bricks, and at Vindolanda between simple wattle hurdles.[66]

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[62] Rowley and Brown (1981) 3.
[63] Rowley and Brown (1981) 3.
[64] Russell and Fentress (2016) 137.
[65] Fantar (1984) 311; Ferron and Pinard (1955) 54.
[66] Roux (2003); Birley (1977) 113.

There are some strong similarities between this technique of construction and faced mortared rubble construction, so common in the Roman world, with a core laid in between the two solid faces. Clay can also be used to hold blocks in place, as mortar would with stone or brick. The fact that this technique existed in Britain before the Roman period is suggested by the late Iron Age ramparts of Burrough Hill hillfort in Leicestershire, where clay is used to 'mortar' the stones in place.[67] In Building H at Watling Court in London, tiles forming the socle for an overlying pisé wall were held in place with brickearth mortar.[68]

Pisé de terre walling

Pisé de terre, or rammed-earth construction, involves the compression of successive layers of soil, sometimes with clay or lime added as a stabiliser, and small gravel inclusions, between wooden formwork. The formwork needs to be relatively solid, and well-braced together, in order to resist the high compressive forces of the packing process. Formwork in the Roman period appears to have been constructed in two main ways: one used horizontal ties between the two panels, which would then leave 'put-log' holes through the wall; the second used vertical uprights on each face of the wall to which the panels were attached, and which would leave vertical grooves in the wall. Packing the soil was achieved using a heavy ramming pole. Once a section of wall had been created, corresponding to the height and width of the formwork, this would be disassembled and moved to create the next section. Walls of this material relied on their massive nature for strength, and thus would tend to be relatively thick, c. 400 to 600 mm, although, as with cob, thinner walls were possible.

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[67] Williams *et al*. (2015) 332.

[68] Perring and Roskams (1991) 79, Fig. 67.

The advantages of pisé are neatly summed up by the translated words of the French architect François Cointeraux, quoted by S.W. Johnson in his 1806 treatise *Rural Economy*:

> "There is every reason for introducing this method of building into all parts of the kingdom; whether we consider the honour of the nation as concerned in the neatness of its villages, the great saving of wood it will occasion, and the consequent security from fire, or the health of its inhabitants, to which it will greatly contribute, as such houses are never liable to the extremities of heat or cold. It is attended with many other peculiarities that are advantageous to the state as well as to individuals. It saves both time and labour in building, and the houses may be inhabited almost immediately after they are finished."[69]

Thus pisé is a relatively rapid construction technique, and has an advantage over cob in not requiring halts in the process to let the lifts of wet earth dry; buildings constructed in pisé can be occupied immediately on completion. Time would be needed to move the formwork however, and the construction and positioning of this would likely be the key skill requirement for the carpenters and builders. The physical work of selecting, extracting, and ramming the earth is relatively simple labour. As with all earth-based mass-wall construction techniques pisé walls have a high thermal capacity, making them effective insulators, and, just as with cob, they can last for significant periods if properly protected with a stone socle footing, sufficient weather-proofing at the top of the wall, and possibly a lime-based wash on the external surface.

Identifying pisé archaeologically is similar, and similarly difficult, to identifying cob. The stone socle might represent a potential indicator of a formerly present earth wall, but following collapse the earth material itself will, just as with cob, be found as a slump of homogenised earth possibly indistinguishable from surrounding deposits. Thus, even if one or other of the techniques is positively identified, distinguishing between cob and pisé can also be very difficult, both taking very similar appearances in the archaeological record. The initial greater compression of the soil in pisé de terre is unlikely to be noticed

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[69] Johnson (1806) 2, quoting Cointeraux (1790).

during excavation on account of time and biological activity loosening the soil; the greater organic content of cob will only be noticed if still-consolidated lumps of material are found bearing impressions of the organics, which themselves will have long since decayed, and closely analysed by a soil micromorphologist. Often the only way to distinguish these two techniques archaeologically is the presence or absence of the put-log holes or vertical grooves, left behind in the stone socle as evidence of the means by which the shuttering or formwork used in pisé's creation was supported; unfortunately these might only have been present in the earth wall itself, and thus are commonly lost in the archaeological record. It is thus not surprising that there is a great deal of uncertainty in archaeological reports in identifying pisé or cob construction.[70]

The origins of pisé as a construction technique are also unclear, but have recently been re-evaluated by Russell and Fentress.[71] The technique is described by both Varro and Pliny, who note that it was found in Spain, but also Tarentum (Varro) and North Africa (Pliny).[72] A North African, possibly Punic, origin for the technique has been suggested, with the earliest most secure evidence of pisé construction in that part of the world in the walls of a 3rd century BC house in Kerkouane, Tunisia, made with formwork fixed to vertical posts set in the socle.[73] De Chazelles goes on to cite the earliest archaeologically attested example of pisé construction using moveable formwork being found in Roman houses at Ampurias, Spain, dating to the Augustan period.[74] In Britain the most secure identification of pisé is at Verulamium (St Albans) in house XXI.2, dated c. AD 180: Frere's excavations uncovered a mortared rubble socle with narrow slots in the top which are believed to have housed the horizontal batons binding the two sides of the shuttering together.[75] In

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[70] E.g. in the Iron Age oppidum at Marignane, argued by Arcelin and Buchsenschutz to be pisé construction (1985, 23), but which De Chazelles disputes (1990, 117).
[71] Russell and Fentress (2016).
[72] Varro *R. R.* I.14.4; Pliny *Hist. Nat.* XXXV.48.
[73] Fantar (1984) 313, Pl. 11–12; De Chazelles (1990) 106, Fig. 15.
[74] De Chazelles (1990) 107-8.
[75] Frere (1983) 237; Perring (2002) 104, Fig. 44.

London, again at Watling Court Building H, a brickearth wall survives with the impressions of two squared uprights in one face, suggestive of the use of shuttering for pisé construction.[76] Russell and Fentress collect together further examples from Britain, including in the south east at Canterbury from late 1st-and 2nd-century phases and at Farningham in a late first-century villa, but also in the west, associated with military activity, such as in the extra-mural baths at Castell Collen fort, Radnorshire.[77]

Mud brick

Mud-brick, adobe, or clay lump construction used un-fired, air-dried earth bricks which often included a significant organic component in their recipe as temper, such as straw or grass. The mixture of wet mud and organic temper would be pressed into rectangular wooden moulds, open at the top and bottom, and left to dry. The sizes of mud bricks in Roman Britain varied, but included 'standard' Roman shapes and sizes such as the "Lydian" brick (1 Roman foot x 1.5 Roman feet).[78] It is suggested that mud bricks would often be produced on the construction site, and so dimensions could vary significantly. Vitruvius offers a brief description of the production and use of mud brick in antiquity, noting that pebbly or sandy clays are not suitable, on account of more easily admitting moisture, and expressing a preference for red or chalky white earths.[79] He describes the laying of bricks with offset joints in order to create a robust wall without lines of weakness; they might be laid in either header or stretcher fashion. Bricks might be mortared in place with a mud mortar or simply stacked. The bricks might be used to make a solid wall, or, as commonly seen in Roman masonry construction, might be used in the fashion of facing for a solid core, in this case possibly also mud, perhaps earth mortar. As with the other earth-based

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[76] Perring and Roskams (1991) 79, Fig. 68.

[77] Perring (1985) 154; Meates (1979) 61; Alcock (1957) 6-7.

[78] The mud bricks from the 2nd century house in Insula XVI at Leciester were 380-430 mm by 250-300 mm, and 50-100 mm deep: Wright (1959) 113.

[79] Vitruvius *De Arch.* II.3.1-4.

techniques, “dry head and feet” were necessary for any longevity of the wall, and thus masonry footings, or occasionally masonry foundations with timber footings beneath the mud bricks are found. Footings, as before, are often between 400 mm and 600 mm wide.

Mud brick conveys many of the same advantages as cob and pisé construction, using cheap materials, requiring little, unskilled labour, and being quick to build with. The technique did however need preparations to be made long before construction took place, as bricks would need to be suitably dry before use. Vitruvius offers several remarks on the drying of mud bricks, suggesting that this should not be rushed by drying during the summer (presumably in Italy), as it will lead to cracking of the brick, but instead production during the spring or autumn is preferable, “ut uno tenore siccescant.”[80] He suggests that the best bricks have been dried for at least two years, and that at Utica in Tunisia bricks were not used before five years of ageing, and the checking by a magistrate. It is perhaps somewhat hard to believe that such diligence might have been practised Empire-wide and at all sites, given that one of mud-brick’s key advantages might be the relative speed and cheapness of construction in this material.

The technique certainly became popular in Roman Britain, and it is perhaps the best attested of the earth-based construction techniques, but this might be on account of being far more easily recognisable in the archaeological record. Whereas cob or pisé construction might leave an amorphous deposit of earth, degraded mud bricks often retain some vestige of surviving edges or faces. In London, for example, discarded mud bricks were found in the fill of a pit at the Newgate Street site, the pit being interpreted as the brickearth quarry for the production of the bricks.[81]

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[80] Vitruvius *De Arch.* II 3.2.

[81] Perring and Roskams (1991).

One excellent example of the technique from Britain is in Insula XVI in Roman Leicester, dating to the 2nd century. This house was described by Wacher at the time of excavation as having been the most spectacular house yet found in Roman Leicester: with a peristyle courtyard, tessellated floors in all seven rooms identified (and at least two proper mosaics), and elaborately frescoed walls, this residence was constructed from mud brick, "laid in yellow sand," on a short masonry dwarf wall, c. 40 cm thick.[82]

This example demonstrates an important point to conclude this survey of earth-based construction techniques: they do not necessarily represent lower quality or lower class construction, as might be assumed, but may instead represent the material of choice for wealthier patrons. Nor did earth construction signify less permanency, nor even simple single storey structures. Perring remarks that "in contrast with the short-lived timber-walled buildings, some… earth-walled town houses stood for over forty years" in London.[83] Watling Court Building H, made from pisé, was decorated with mosaics and wall paintings, and stood two storeys high.[84]

A further difficulty that we have to deal with, in common with that now widely recognised for stone building materials, is that building earth may well have been reused once a building went out of use. The material is easily quarried out of a standing wall and simply re-puddled, if being used in cob construction, or remade into bricks or rammed between formwork. Perring and Roskams note this in their discussion of building materials in Roman London.[85] They firstly note the absence of clay destruction debris in the vicinity of demolished early buildings, despite it being present surrounding buildings which had burnt down or collapsed, such as Newgate Street building VIII.13 or Watling Court building VI.2. Secondly they note trenches apparently dug to recover brickearth from

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[82] Wright (1959) 113; Wacher (1975) 350, Fig. 78.
[83] Perring (2002) 102.
[84] Perring and Roskams (1991) ix.
[85] Perring and Roskams (1991) 67.

buildings at the Iron Monger Lane site. Finally, most tellingly, they record fragments of wall plaster contained within the brickearth walls of several buildings, indicating the spoliation of brickearth from earlier buildings.

2.3.2.2. Earth-Fast Footings for Principal Posts with Infilled Walls

The second constructional system to explore, in use in Britain in the Roman period, was founded on the embedding of timber principal posts, piles, or studs directly into the ground, and to which various different forms of wall fill or cladding could be fastened. The posts would be driven or buried into the soil, either into post-holes, or into a foundation trench. Once in place, the holes or trench are likely to be packed or backfilled with earth, gravel, or stones.[86] The simplest way to build in this way involves the use of posts of circular section, with a diameter of between c. 20 and 50 cm, i.e. a log that had little working beyond the removal of bark and some of the outer sap wood.[87] However, work carried out in London in the last three decades has uncovered a great number of preserved *in situ* and re-used timbers, the careful examination of which demonstrates that there were many diverse methods used in Roman earth-fast construction.[88]

These demonstrate the great variety of techniques available to and used by builders in Roman Britain, and show that we do need to think beyond the simple, and archaeologically relatively obvious, post-hole built structures that immediately come to mind when timber buildings are discussed.

Post-holes are difficult features to interpret. Individual examples are often not sufficient to allow the postulation of a building, given that posts might conceivably be driven into the ground for a number and range of uses beyond structural functions. Groups of post-holes need to be seen in plan, with a discernible pattern or shape to their arrangement, in

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[86] Although note the discussion below on the packing of voids left by rotted posts; *cf.* Reynolds (1995).
[87] Ellison and Drewitt (1971); Ulrich (2007) Table 1.
[88] Goodburn (1995).

order to be confident in their role in construction, and even in this case they might rather be for secondary support to another construction method or components within a building. It has been suggested that, for Roman construction, the packing of post-holes with stone might indicate a more important function.[89]

The spaces between these earth-fast footings could be filled in with various techniques. These included wattle and daub walls: a combination of flexible wooden sticks or strips, woven either horizontally or vertically, and coated with a mixture consisting of some combination of mud, clay, dung, and straw. Alternatively boards, sawn or hewn from logs, or earth or turf walls might be used.[90]

Evidence for these construction techniques principally comes from the arrangement of post-holes, trenches, or post-pads. In rare, exceptional circumstances, including as a result of fire, or waterlogged ground, timbers and remains of wattle and daub panels can survive, for example in the civil settlement at Caerleon where a collapsed wattle and daub panel was found preserved by fire damage.[91]

The simple post-hole construction technique was certainly not a new technology in Roman Britain, but one that is evidenced as far back as the Bronze Age, the characteristic technique used to make 'roundhouses,' and also rectangular structures in these periods.[92] Circular gullies, traditionally known as "drip gullies" (despite the physical implausibility of this explanation for their creation), together with circular arrangements of post holes, are taken to indicate their presence.[93] At Glastonbury preserved wattle hurdles have been discovered dating to the 2nd or 1st centuries BC.[94] These building types still continued to be

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[89] Booth (1997) 154.
[90] For Roman plank cladding see Brigham *et al.* (1995); Perring (2002) 97; for details of turf construction see Walker (2006); Wilkinson (2009).
[91] Goodburn (1991); Keevill (1995) 33.
[92] Guilbert (1981); Pryor (1991).
[93] On "drip gullies" *cf.* Reynolds (1995) 22. For structures of the Iron Age in the Upper Thames Valley: Harding (1972).
[94] Cunliffe (2004) 447.

built and were common in Roman Britain, particularly earlier in the period and in rural areas. The continuity of the practice is exemplified at Quinton, Northamptonshire, where roundhouses were used on this rural settlement both in the late Iron Age into Roman period, to around AD 50, but a new one was also constructed in the late 3rd or 4th century.[95]

Such construction required little in the way of carpentry and joinery skills, or complex tools, compared to the more sophisticated jointing systems brought to Britain by the Romans and seen elsewhere.[96] Simple axes for cutting or shaping timbers were essentially the only tools required, and construction might be relatively low in manpower, skill, and complex materials.[97] Nevertheless, in spite of their simplicity, such structures, at least in the larger cases, still required significant quantities of building materials: the reconstructed Pimperne House, a Bronze Age roundhouse with a diameter of just under 13 m, made using technology little changed into the Roman period, required over two hundred mature oak trees for structural timbers, 0.5 hectares of hazel coppice for the wattle cladding, and c. 12 tonnes of straw for the roof.[98] Earth-fast timber construction was thus particularly advantageous in regions with readily available timber, but significant levels of construction using this technique will have necessitated careful woodland management.

It is a matter of debate as to how long-lasting such structures might be. Wattle and daub walling might last for under a decade in poor conditions, evidenced by ethnographic examples, and in Roman London where seven phases of wattle and daub buildings were constructed over just a 60 year period.[99] It may however last much longer in ideal conditions, as is demonstrated by the fact that these construction techniques can still be

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[95] Friendship-Taylor (1979); (1999). *Cf.* Perring (2002) 86.
[96] Perring (2002) 91-2, and Fig. 36; Ulrich (2007) 59 ff.
[97] As Ulrich (2007, 75) remarks, this explains the frequent use of piles or posts by the Roman military.
[98] Reynolds (1979); Drury (1982).
[99] McIntosh (1974) 163; Perring and Roskams (1991) 81; Reynolds (1995) 22. *Cf.* Vitruvius *De Arch.* II vii.2.

seen today in surviving medieval houses. Similarly large timber beams might last centuries if kept dry and protected from insect damage. However, with all earth-fast techniques, the act of embedding structural timbers directly into the soil gives no protection from damp: even seasoned oak in these conditions might be expected to rot within five to ten years of construction, and thus we might see such structures as being very short-lived and ephemeral.[100] However, the reconstructed Pimperne House demonstrated that, despite the rotting away of the bases of a significant number of the structural timbers, so that they were essentially suspended in mid-air from the roof, the houses still stood, and the voids could either be packed so that the timber was again providing support, or the timber could be entirely replaced without cost to the stability of the structure.[101] Reynolds points out that "a 3 m length of oak 300 mm in diameter weighs in excess of 150 kg and is virtually impossible to crush in its length:" it is on this fact that the superstructure of the Pimperne House was still stable despite the total structure weighing in at around 40 tonnes, and even with the rotting of several of its supports.[102] We should therefore assume that Romano-British builders would have understood these processes, having inherited a timber building tradition over a millennium old; with maintenance these buildings could have lasted for decades.[103]

2.3.2.3. Timber Baseplate Footing, with Timber Frame Construction and Infilled Walls

The fashion for timber baseplate construction, according to Ulrich, actually stems from pre-Roman tradition in northern Europe and England.[104] The erection of a complex, braced timber frame above this however was, according to Perring, a new technology first appearing in Britain in the Roman period.[105] Putatively, this method of construction

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[100] Goodburn (1991) 192; Adam (1994) 87.
[101] Reynolds (1995) 23.
[102] Reynolds (1995) 23-24.
[103] It is worth noting that, generally speaking, wattle and daub would not last as long as cob, mud-brick, or pisé de terre, and nor does it have as high a thermal mass, making it a poorer insulator: Easton (2007) 11.
[104] Ulrich (2007) 76.
[105] Perring (2002) 88.

became the most commonly used technique.[106] It involves the erection of a braced timber frame above a horizontal baseplate beam, resting on the ground or in a shallow trench. This baseplate beam is usually a squared timber, c. 150 mm deep, in which mortises were cut to take the uprights of the frame.

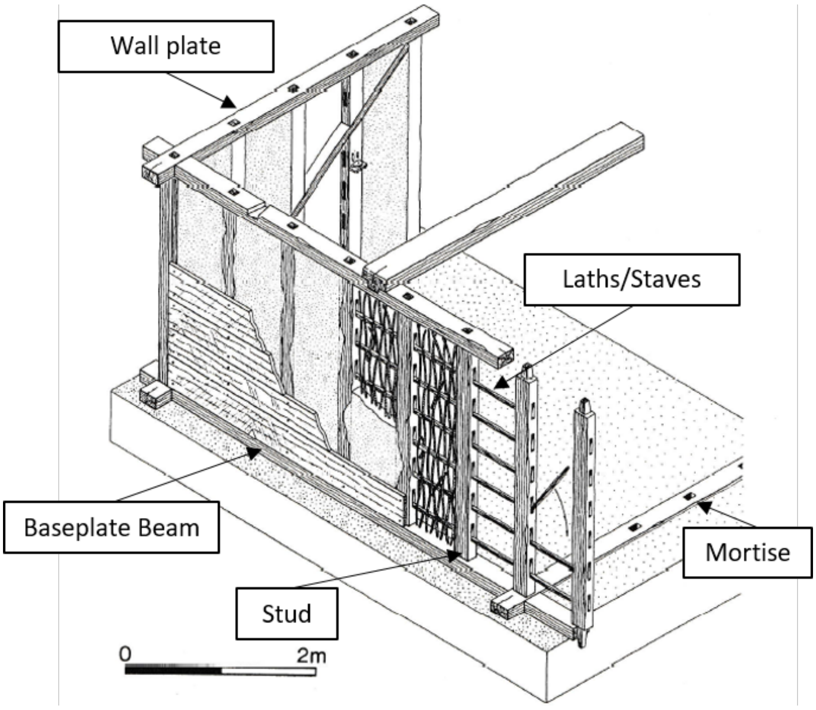

Figure 2. 1: Reconstruction drawing showing a timber framed building, reconstructed from the timbers and joints discovered at Cannon Street. (After Goodburn 1991 Fig. 2).

These uprights, known as studs, were again made from squared timbers, which in the examples from Cannon Street were c. 80 to 160 mm in side lengths and 2 to 2.5 m tall; these would have supported the "wall plates" above.[107] In between the studs, laths or staves might have supported wattle and daub panels, woven vertically.[108] Alternatively rammed clay or mud, cob, and/or sawn timber planking might have provided the cladding.[109] Planks have survived from the Courage Brewery site in Southwark, belonging to a warehouse building and dated by dendrochronology to AD 152-3, measuring 35-38 mm thick and 250-400 mm wide, fastened edge to edge rather than overlapping; planking

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[106] Adam (1994) 122; Perring (2002) 83.
[107] Goodburn (1991) 200.
[108] As at Cannon Street, Goodburn (1991) 191, *cf*. Fig 2.1.
[109] Goodburn (1991) 191; Perring (2002) 96-97.

could be used just as an external cladding, or on both the inside and the outside of a wall-filling such as wattle and daub.[110] This technique is also seen at Carlisle, York, Vindolanda, and Heronbridge.[111] Rafters would have sprung from the wall plate, supporting either a thatched, ceramic, or stone tiled roof (more on this below).

The evidence left behind for the use of these techniques is rare, and only survives in the case of waterlogged or charred deposits. Thus we are confined, in discussing timber-framed buildings in Roman Britain, to a small number of examples. Timber framing represents a more technologically advanced construction technique than simple post-built structures, requiring greater carpentry skills and more complex tools (such as adzes, planes, drills, frame saws, cross-cut saws) for shaping the timbers, cutting out precise mortises, dovetails, rebates, and scarfs, carving the tenons of the uprights, and sawing planks.[112] These were techniques and tools introduced by the Romans to Britain.[113] Herculaneum furnishes us with some of the best examples of timber-framed buildings on account of the exceptional preservation of wood there. The College of the Augustales, constructed in timber framing with *opus incertum* infilling, is one such example.[114] The absence of this construction technique in Britain before the Roman conquest must have made its emergence a very overt display of new fashions and technologies, and it is generally accepted that military influence was the significant promulgator of this; through military involvement in the construction of buildings in the towns of Roman Britain the techniques will have reached wider popularity and the skills, tools, and technologies spread from here.[115]

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[110] Brigham *et al.* (1995).

[111] Perring (2002) 97.

[112] Goodburn (1991) 199, Fig. 8; Adam (1994) 100-101; Perring (2002) 83, 91-92.

[113] Weeks (1982).

[114] Adam (1994) 122.

[115] *Cf.* the well-preserved timber-frame base at Valkenburg, Netherlands: Glasbergen *et al.* (1974); Hanson (1978); Evans (1994); although *cf.* Blagg (1980).

Timber frame superstructures facilitated the construction of large and complex buildings, including multi-storey structures (although we should not discount that pre-Roman post-built structures may also have had multiple storeys). Again however the rotting of timbers left in contact with the ground could become a problem, and so the life-span of buildings constructed in this way might have been short, particularly in damp environments, 10 years or so seeming to be the widely acknowledged figure for the life-span of oak in unprotected situations. This made the technique ideal for military construction, with camps and forts either temporary, to be abandoned within a few years, or re-built in a more permanent fashion if they were to become a fixed placement: in both situations, early wooden structures did not need longevity.[116]

2.3.2.4. Masonry Footing Constructions with Various Superstructures

Masonry construction remains one of the best attested construction techniques in Roman Britain, although this has to be, in many cases, because of its far better survival rate than other techniques rather than because of its predominance as a technique. This technique made use of courses of stone, laid more or less regularly, and with or without some kind of binding agent, lime mortar or mud. The method might be used for the entirety of the foundations and superstructure, making a complete masonry building, or might be used just as a footing to support a superstructure in a different technique or material. These include those described above, including timber-framed superstructures (with the various wall infill types discussed with it), or the various earth-based techniques discussed before that, and for which “dry feet” were mentioned as being integral for long survival.[117] As these techniques have already been covered, we will focus here on the masonry aspect of such structures. A simple way of attempting to tell whether a masonry footing is just that, or is part of an entire masonry wall which has had its upper courses robbed, is to examine if the

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[116] Evans (1994).
[117] Perring (2002) 102.

height of the top course of surviving masonry is relatively consistent along the wall. If so this would suggest it was just a footing, as it is unlikely that a wall would have been robbed to a consistent height along its span.

Masonry can be used in a diverse range of ways, including (rarely in Britain) ashlar, that is, neatly squared blocks that fit tightly together with little space in between, or (more commonly in Britain) simple rubble construction or faced mortared rubble.[118] Facing styles included unworked or roughly squared blocks laid in horizontal courses, and *tegulae* or bricks were occasionally used to create string courses, bonding the facings with the mortared rubble core.[119] The use of brick-facing was however limited in Britain. Masonry footings tend to range from between 25 cm up to 90 cm in width, and vary greatly in the quality of their construction.

Above this footing a number of different superstructures could be constructed. The walls could be taken up to the eaves entirely in masonry, continuing the techniques used in the footing.[120] Alternatively, the masonry footing could provide a base for a timber frame, constructed as described before, but with the base plate lying on top of the masonry dwarf wall: this would give stability to the frame, particularly useful when building on uneven ground, and would protect the base plate and bottoms of the studs from damp, thus extending the life of the building. Adam notes that oak timbers protected from the damp of the ground in this way might last more than 60 years.[121] The panels of this frame might be infilled or clad with various techniques, as described above, including wattle and daub and timber planking. Alternatively the earth-based construction techniques described above might sit on top of dwarf walls, again extending their life by keeping their 'feet' dry.

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[118] Adam (1994) 21 ff.

[119] Blagg (1996); Neal (1996); King (1996).

[120] E.g. the Meonstoke collapsed wall: King (1996).

[121] Adam (1994) 87-88.

Masonry construction was facilitated in particular by the use of lime mortar; dry-stone walling and, as noted above, earth mortars were used, but the performance of these was far below that of lime mortar. This new technology brought into Britain by the Romans thus allowed the technique to proliferate.

Evidence for construction using these techniques can be problematic. Masonry wall-footings are, along with post-holes, the most commonly identified indicators of archaeological buildings, so in the first place are easily recognised, either from the stones, or stone-robber trenches. However, as briefly discussed above, we often only find masonry truncated to a low height on account of the collapse of the building, stone robbing, and later land-use such as ploughing: as such, with so many options for the erection of the superstructure, of varying archaeological visibility, it can be very difficult to know what was used above the dwarf walls, and indeed how tall such a structure might have been.[122] Evidence of more stonework on site could indicate a masonry superstructure, and the collapsed gable walls mentioned above, and better preserved buildings such as the baths basilica at Wroxeter, attest to this.[123] Claims have been made in the past that a building did or did not have a second storey based on the width of the wall footings, but this should be seen as a poor indicator.[124]

Masonry footings had many advantages over other techniques, including (if built correctly) improved stability, the ability to lift wooden and mud cladding techniques away from the damp ground, and probably improved security and protection against vermin, flooding, and fire. However, it might also have come at greater cost, depending on the

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[122] Keevill (1995) 33; Strickland (1995).
[123] Ling (1992); Barker (1997).
[124] Neal (1996) 33.

availability of stone nearby, and the many examples of the later addition of buttresses to walls demonstrate the problems of subsidence if poorly built.[125]

2.3.2.5. Roofing

Finally it is worth noting the methods of roofing buildings. This is a subject that is often neglected in studies of construction, major, *in-situ* remains tending to be of walls, with roofs poorly represented archaeologically. For most roofs a timber framework is required, and a combination of Roman evidence and medieval vernacular architecture can provide insight into the form these may have taken. It seems likely that most roofs in Roman Britain would have been relatively simple gable roofs (as hinted at by the gable-end wall collapses noted above). For smaller spans, perhaps of 5 m or less, these would simply require a ridge beam (running horizontally along the length of the roof ridge) and rafters (running diagonally from the wall-plate to the ridge); for greater spans truss construction would have been required. Trussed roofs are discussed by Vitruvius (*de Arch.* IV.2.1.) and are well attested in the Roman world.[126] Truss structures would have been made from a ridge board, rafters, tie-beams (running horizontally between the wall-plates across the building), and purlins (running horizontally between rafters). Other collar and strut structures may have been used to further strengthen the roof, such as kingposts or queenposts, and boards may have lined the rafters in order to support the roofing material above. There is no evidence from the Roman period for the well-known medieval technique of cruck construction, but what might be rafters from a Roman hipped roof have been identified, reused, at Scole, Norfolk, showing potential knowledge of this technique of roof construction.[127]

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[125] E.g. Keevill (1996) 47.

[126] *Cf.* Ulrich (2007) 138 ff. Of interest is the ?1st C. BC relief found in the Campus Martius depicting an arena with a trussed roof above: Coarelli (2001) 46. In Britain, for the reconstructed truss roof at Southwark see Brigham *et al.* (1995) 27-31; for the roofs from the legionary fortress at Inchtuthil see Shirley (2000) 25.

[127] Flitcroft and Tester (1994) 321.

Organic materials would have been the most commonly used coverings in Britain, particularly on lower status buildings.[128] Such techniques utilise easily available local materials and are shown by medieval and modern comparanda to be highly effective. Such materials might include the use of thatch, wooden shingles, or turfs or sod.[129] All of these materials are difficult to identify archaeologically. Caesar describes his winter quarters in Gaul "quae more Gallico stramentis erant tectae," "which in the Gallic fashion had roofs of straw," attesting to the use of the technique in the wider region.[130] Grimes tentatively proposes the discovery of the remains of a collapsed thatch roof in London.[131] Pliny notes the use of timber shingles to roof buildings in Rome down to the 3rd century BC, and four possible shingles were found at the Courage's Brewery Site, Southwark.[132] Shirley regards shingle covering as being the most likely technique used for the majority of the buildings in the Inchtuthil fortress.[133] Generally speaking, the absence of other roofing materials, i.e. ceramic or stone tiles, has been taken to indicate the use of thatch or one of these other organic materials, on account of the fact that it is unlikely that the entire assemblage of stone or ceramic roof tiles would have been scavenged for re-use, as these are fragile, liable to breaking, and so small fragments at least would be expected to remain even after thorough robbing.[134]

Ceramic and stone tiles are far more archaeologically visible as roofing materials: ceramic roofs were constructed from overlapping *tegulae* and *imbrices*, held in place by their own weight (necessitating a roof pitch of c. 20-30 degrees), or occasionally with wooden dowels, nails, or mortar; stone roofs were generally made from four- five-, or six- sided 'slates' or 'tile-stones,' often fixed in place with metal or wooden pegs (allowing a much steeper roof

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[128] Perring (2002) 120.
[129] Walker (1996).
[130] Caesar *de Bello Gallico* V.43.
[131] Grimes (1968) 97.
[132] Pliny *Hist. Nat.* 16.36; Brigham *et al.* (1995) 23 and Illus. 18.
[133] Shirley (1996) 117-8.
[134] Perring (2002) 120.

pitch, up to c. 60 degrees).[135] Given the great weight of such substantial roofs, easily multiple tonnes, significant carpentry would have been needed to support this. Shirley estimates that tile roofs were roughly twice the weight per area than shingle roofs; for the "Tribune's House" at Inchtuthil, if roofed with tiles at a 20° pitch would have required 54% more primary roof timbers than if roofed with shingles at a 30° pitch.[136] In terms of weight of roof covering, she estimates the use of 90 tonnes of tiles, or 40 tonnes of shingles, or 75 tonnes of thatch, taking into account the varying roof pitches, material overlap, and roof overhangs.[137]

In contrast to the pre-existing thatch, shingle, and sod techniques, certainly ceramic roofing, and in its widespread use, stone roofing, appeared only from the Roman period: CBM seems to have appeared in the AD 50s (as demonstrated by the "Nero" stamped tiles found at Silchester, produced at Little London), whilst stone roofing seems to have become more common from the later 2nd century onwards, particularly in the south west of Britain and into the Midlands.[138]

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[135] Brodribb (1987).
[136] Shirley (1996) 117.
[137] Shirley (1996) 118.
[138] Machin and Warry (2017) pers. comm.; Williams (1971b).

2.4. Roman Architecture in Oxfordshire

Having surveyed the general techniques which were available to builders in Roman Britain, focus will now turn to the techniques observed in the study area. Oxfordshire, like much of Britain, generally offers poor preservation of Roman buildings: widespread agriculture and the ploughing that has gone with it, the processes of natural decay, and spoliation for re-use have, together, contributed to a general lack of substantial Roman building remains being found in the county. In the excavation reports, stemming from both research and commercial excavation, details of precise building shape and dimensions, the constructional technique, detailed descriptions of materials, and insight into associated finds which might give further clues to the building technique (e.g. quantity, shape, and material of rubble in the vicinity), are seldom all present (although it should be recorded that the reports on two sites discussed below, Asthall and the extramural settlement at Alchester, both have excellent, in-depth discussion of construction techniques.[139]

For this survey sites were identified using the "Rural Settlement of Roman Britain" project database.[140] Sites were researched which had category tags which suggested structural evidence, coming to a total of 129 sites across the county. To this list were added the two town sites in the county, Alchester and Dorchester on Thames. As discussed in the introduction to the study area, Oxfordshire lacks any particularly large Roman settlements, with Alchester and Dorchester the two largest sites in the county, classified at the level of "Roman small town."[141] Findings from all 131 sites will not be given, but specific examples are discussed and broad patterns drawn out. Here five sites, representing small towns, roadside settlement, and rural settlement, are considered, covering

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[139] Booth (1997); Booth, Evans, and Hillier (2002).

[140] URL: http://archaeologydataservice.ac.uk/archives/view/romangl (accessed 13/12/16)

[141] Henig and Booth (2000) 51 ff.; Booth *et al.* (2007) 33ff.

categories seen as representative of the range of settlement types in the county. The locations of all of the sites discussed can be seen in Fig. 1.1 above.

2.4.1. Dorchester on Thames

Beginning with Dorchester itself, around the modern village several locations with structural evidence have been excavated. At Frere's "Site B" in the allotments, dug in 1962, a single building was found sitting adjacent to the main Roman road through the town.[142] The excavator recorded a rectangular structure 12 metres by 6 metres, with 70 cm thick external walls consisting of "limestone set in mortar, at the most two courses thick" (Fig. 2.2).[143] Internally the building was recorded as being divided into three rooms, and given the find of a coin of Honorius underlying the structure, it must date to the very end of the 4th century or the early 5th century. On account of having no significant foundations, Frere notes the probability that "such flimsy bottoming supported a half-timbered upper structure."[144] No further details are given about the character of the construction technique or materials, and no roofing material is mentioned. He does note that the walls were heavily robbed, with clear robber trenches removing the eastern two-thirds of the building.[145]

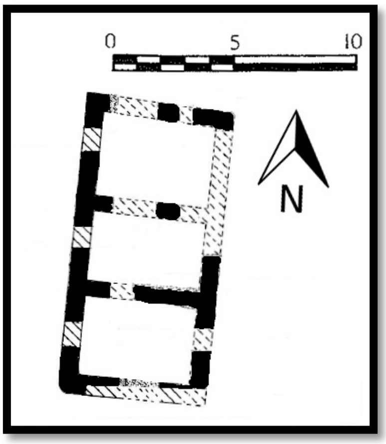

Figure 2. 2: Plan of Frere Building 1.i, Dorchester on Thames (after Frere 1962 Fig. 6).

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[142] Frere (1962).
[143] Frere (1962) 121.
[144] Frere (1962) 121.
[145] Frere (1962) 121.

A second site with structural evidence is that excavated by Rowley and Brown in 1972 on the Beech House Hotel site, roughly on a line of where the northern wall of the Roman town was expected.[146] The main Roman structure excavated was difficult to interpret, being heavily robbed, but seems to lie on a south-east to north-west alignment (as opposed to the strict north-south alignment of the road system as presented by Frere), and might comprise an "out-building" as opposed to a significant structure in its own right.[147] The main phase of construction seems to date to the mid-3rd century, and consists of two parallel stone foundations running for at least 6 m (continuing beyond the extent of the excavation), c. 2 m apart; the foundations were c. 0.75 m wide on average.[148] The materials of this construction and of debris in the vicinity consisted predominantly of limestone rubble, suggested by the excavators as originating in either the Wheatley Limestone or the Portland Limestone, both of which outcrop within 10 miles north of Dorchester (see Chapter 3.2.4 and Catalogue 1 for more on the regional geology, and Chapter 5.5.1 on building stone sources).[149] Flint and chalk were also noted in abundance, with a suggested origin, based on the nearest potential source, of the Wittenham Clumps just south of the Thames as it passes Dorchester. On account of the lack of stone sources in the vicinity, they predict that it was likely that few buildings were built entirely from stone, suggesting instead cob and/or timber walls sitting on stone dwarf walls. They use the example of a thatched cob-built boundary wall towards the northern end of the modern village as evidence supporting this hypothesis.[150] Ceramic and stone roof tile were also found.[151]

The most recent structural evidence excavated in the town has been uncovered by the ongoing University of Oxford and Oxford Archaeology project in the allotments. A wall

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[146] Rowley and Brown (1981).
[147] Rowley and Brown (1981) 23.
[148] Rowley and Brown (1981) 5-8 and Fig. 3.
[149] Rowley and Brown (1981) 3.
[150] Rowley and Brown (1981) Plate 1.
[151] Rowley and Brown (1981) 6.

footing or foundation of a building, c. 10 metres in length, with returns at either end, set within an enclosure ditch, has been found (Fig. 2.3), situated about 20 metres to the west of the central north-south Roman road, and apparently aligned with it.[152] The evidence consisted of a straight row of roughly shaped masonry blocks of mixed materials, including limestone, sandstone, and flint, and with occasional lumps of mortar; what this represents is difficult to understand, as, being only one or two blocks wide and generally only one course high with no construction cut visible, this would be a very shallow and insubstantial foundation, or an even more flimsy wall footing. Undoubtedly it has been heavily robbed. The full dimensions of the building are also not known, the majority of the structure again lying outside of the extent of the trench. Returns, running west at right angles to the main north-south wall, head back into the trench edge.

Figure 2. 3: Insubstantial remains of a section of the front wall of a large, late 2nd Century building (total frontage of c. 20 m) at Dorchester on Thames. Scales 2 m (horizontal) and 1 m (vertical).

Elsewhere in these excavations traces of what was perhaps a cob wall were found. Lying perpendicular to the north-south Roman road, about 7 metres to its west, this was conceivably an internal wall, given the lack of any sign of a footing, and that it was only c.

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[152] Booth (2012) 53; (2013) 62.

150 mm thick. A number of post holes, some with apparent alignments, have been found across the trench, but as yet no building plans have been identified from them.

2.4.2. Alchester

Alchester provides further evidence of constructional techniques in Roman Oxfordshire, again in a moderately sizeable town. Excavation in the 1920s revealed the plans of multiple buildings, both stone-footed and post-built, the former reflecting the significant crop-marks which can be seen in aerial photographs.[153] The town lies around 1 km from outcrops of the Cornbrash Formation, and the analysis of stone from the extra-mural settlement noted a dominance of this stone, together with examples of Forest Marble (outcropping in the valley of the Gagle Brook, between 1 and 4 km north west of the town), but also possible Stonesfield Slate, available just off Akeman Street about 20 km west of the town.[154]

Booth *et al.* offer a detailed discussion of the structures found in the extra-mural settlement to the north of the town. Nine of the 22 structures observed had stone foundations and wall footings, but only four of these are described as having had "regular foundations entirely of stone."[155] Eight structures were founded with earth-fast posts, two structures on timber sill-beams, and one on stone post-pads.[156]

Only one structure, a small circular building (Building A), is thought to have been walled in stone up to the eaves.[157] This structure, together with a large, circular, stone-founded building (Building B), are seen by the excavators as possibly being part of a regional fashion for Roman period stone-founded roundhouses with a domestic context, comparable examples having been noted at Redlands Farm (Stanwick, Northamptonshire), Bourton-on-the-Water, and Birdlip (both Gloucestershire).[158] The remaining buildings are

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[153] Hawkes (1927); Foster (1989).
[154] Booth, Evans, and Hillier (2002) 253.
[155] Booth, Evans, and Hillier (2002) 435.
[156] Booth, Evans, and Hillier (2002) 437-8 and Table 10.1.
[157] Booth, Evans, and Hillier (2002) 435.
[158] Keevil and Booth (1997) 43; Renfrew (1978); Timby (1998) 379-80; Mudd *et al.* (1999) 242-55.

presumed to have had timber superstructures, or, in the case of the stone footed buildings, possibly earth walls.[159]

Recovery of full building plans was difficult, and full dimensions and internal arrangements were rarely clear.[160] Some CBM was recovered from the site, including roof tile, box flue tiles, and thicker bricks interpreted as remnants of underfloor heating systems. The latter evidence was noted as unlikely to come from any of these relatively insubstantial buildings, but occasional ceramic tile roofs were accepted as possible; no stone roofing material was recovered, and so thatch or shingled roofs were suggested for the majority of these buildings.

2.4.3. Asthall

The Roman settlement at Asthall, situated on the west bank of the River Windrush, appears to straddle Akeman Street with the road as its principal axis, and offers evidence of constructional techniques in a "roadside settlement." Structures were revealed during excavations in 1992 for a pipeline; the nature of the excavation only gave a limited view of the Roman features impacted by the narrow line of the trench, and no complete building plans were revealed, but Booth makes the case that what was seen represents so-called "strip buildings."[161] These buildings were characteristic of road-side settlements, where frontage facing onto the road was at a premium, leading to long, thin rectangular buildings with their narrow edge facing onto the road. During the earliest phases of the town, in the mid- to late-first century, these were of timber, using beamslot and earth-fast post construction, but by the mid-second century these had been rebuilt with substantial stone foundations.[162] Booth discusses whether these deposits represented solely foundations or dwarf walls, or whether the stone carried up to the eaves; the walls of Building F, for

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[159] Booth, Evans, and Hillier (2002) 436.

[160] Booth, Evans, and Hillier (2002) 438.

[161] Booth (1997) 153; Henig and Booth (2000) 65.

[162] Booth (1997) 153-154.

example, were c. 0.6 m thick, and those of Building H 0.75 m thick, which might suggest that they were capable of supporting a two-storey building in stone, based on comparison with the two-storey collapsed walls of buildings at Carsington (Derbyshire), Meonstoke (Hampshire), and the villa at Redlands Farm, Stanwick (Northamptonshire).[163]

In terms of building materials, stone was noted as being abundant across the whole site, understood to be building stone and surfacing stone for yards and streets.[164] Most of the building stone was identified as Forest Marble, outcropping at distances of less than 1 km from the town, but with occasional samples of a shellier oolitic limestone, identified as possibly Clypeus Grit, which must have come from slightly further afield. A few stone roof tiles were found, again identified as being of Forest Marble, although a number of small fragments of what were thought to be stone roof tiles in a dark purple medium-grained micaceous sandstone were also uncovered, identified as possibly being Old Red Sandstone, perhaps from the Welsh borders. Some ceramic roof tiles were found, but only a relatively small quantity; a variety of fabrics were seen, including one tentatively linked with the production centre at Minety, Wiltshire. This relative lack of large quantities of roofing material should perhaps be read as implying significant use of biodegradable roofing material, such as thatch or shingles.

2.4.4. Barton Court Farm

Barton Court Farm, near Abingdon, offers construction evidence from what became a moderately high status Romano-British rural settlement. [165] Two main phases of construction were identified during excavation. The first consisted of a beamslot construction timber-built farmhouse, dating to the late 1st C. or early 2nd C, and measuring 8.5 m by 28 m, aligned with its long axis east-west.[166] This had only a relatively short period

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[163] Booth (1997) 154.
[164] Booth (1997) 102-3.
[165] Miles (1986).
[166] Miles (1986) 9-10, 30, and Fig. 7.

of use, seemingly falling into abandonment by the mid-2nd century, followed by a century of no, or very little, activity.[167]

This structure was replaced in the late 3rd into the 4th C. by a substantial stone founded farmhouse or villa (or “cottage villa”), 10 m by 25 m, set within a ditched enclosure, and the long axis aligned perpendicular to the earlier building, north-south.[168] Partitions could be detected within the structure, dividing it into six or seven rooms, with a cellar at the northern end of the range, and a corridor along the eastern side. Excepting the cellar, only the foundations of the ground-level walls remained, c. 0.75 m wide, formed of Corallian ragstone set in a foundation cut. These had been significantly robbed, with at most just one course remaining in places.[169] Blocks were laid in slanting courses, a technique which the excavators claim would have provided extra stability, but this seems doubtful – stone laid in more-usual horizontal courses would have more evenly spread the compressive forces of the weight of the superstructure, and indeed an uneven surface of stone would have been a more difficult surface on which to build.[170] It seems more probable that such an arrangement might have been to facilitate drainage, perhaps with an earth binding creating a flat surface on top on which a timber or earth superstructure could be built, with better drained “feet” to increase its longevity.[171] The foundations of the stone villa at Ditchley Park were also begun with a layer of pitched stone, but with Radford preferring the idea that the walls there were taken up to the eaves in masonry.[172] The excavators do not make any comment on the materials or construction technique of the superstructure, only noting that the foundations were “substantial enough to have supported two storeys,

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[167] Miles (1986) 9-13.
[168] Miles (1986) 12-15, 30-31, and Fig. 8.
[169] Miles (1986) 12-13 and Fig. 9.
[170] Miles (1986) 12-13.
[171] *Pers. Comm.* J. DeLaine (18/10/17).
[172] Radford (1936) 39-40.

although it has been claimed that this would not usually be the case with buildings of this kind."[173]

To the east of the villa were a series of post-holes, interpreted as an adjoining timber annexe.[174] In the cellar, viewed as a late addition to the villa, four courses of limestone blocks survived in a small fragment of the south wall, along with a more complete mosaic pavement, but the vast majority of the walls of even this subterranean room had been robbed. A large quantity of *tesserae* were excavated across the structure, generally in plain white/cream limestone, showing that one or more rooms had mosaic paved floors, and the excavators refer to "moulding" being found "around the windows and doors, and forming pilasters." It seems unlikely that the Corallian ragstone was suitable for this finer carving, but the material of these is not elucidated, and the excavators may well be talking about stucco. Painted wall plaster is common across the site. Regarding the roofing material, the report notes that both ceramic and stone roof tiles were found in quantities at the site, suggesting a roof of mixed materials across its different sections. A range of agricultural-character structures were identified in the vicinity, including a corndryer, a regular grid arrangement of "ditched paddocks and yards" occupying 1.4 ha, two wells (one with a square well-house built of coursed ragstone), and waterholes.[175]

2.4.5. Shakenoak Villa

The lands of Shakenoak Farm, situated c. 2 km south of Akeman Street where it runs through the Roman roadside settlement of Wilcote, has yielded two significant Roman structures showing the architectural development of a high status productive and residential villa estate.[176] Building B seems to represent the earlier residential villa; construction activity at the site focused around the late 1st and first half of the 2nd century

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[173] Miles (1986) 30; Richmond (1969) 53.
[174] Miles (1986) 12-13 and Fig. 10.
[175] Miles (1986) 12, 14-15, and Fig. 11.
[176] Brodribb *et al.* (2005).

AD, but with a clear diminishing of the site and change of use into the 3rd and 4th centuries. Conversely and perhaps in opposition to Building B, Building A seems to have had productive and agricultural functions through from c. 100 AD to the early 3rd century, when it was rebuilt into a high status residential villa which remained in use until the end of the Roman period.[177]

Beginning with Building B, Roman occupation began in the Flavian period with the construction of a winged building of 25.9 m by 12.8 m, the wings projecting to the south by c. 2.3 m, and which contained 10 rooms. In the first half of the 2nd century the building was extended by the addition of a 3 m wide corridor around the north, east, and west sides of the villa. A fine stone pilaster appears to relate to this phase of construction, its un-weathered state leading the excavators to suggest that it may have flanked an internal doorway.[178] In the mid-2nd century the building was extensively remodelled, with an extension of the floor plan by c. 10 m to the west and the complete modification of the layout of all but three rooms. The building was now significantly larger, with plastered and painted walls (although apparently a lack of any mosaics), corridors along the north and south sides of the range, new projecting wings to the south, and a hypocaust inserted in the western corridor. In the early 3rd century several rooms were closed off and hearths were inserted into the north corridor, before in the middle 3rd century roughly two thirds of the building was demolished.

The foundations of the building were a c. 25 – 30 cm depth of limestone rubble set in earth, on top of which masonry footings sat: these were formed of regular, hammer-dressed limestone facing (block face sides of roughly 12 to 20 cm and a depth of 15 to 23 cm) on an undressed or only very roughly dressed mortared rubble core.[179] The width of the walls,

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[177] Brodribb *et al.* (2005) 4; 80.
[178] Brodribb *et al.* (2005) 92.
[179] Brodribb *et al.* (2005) 80.

where surviving, was c. 60 to 76 cm. The authors note that it was not clear whether the walls were carried in masonry up to the eaves, or whether a timber frame (or, unsaid, earth walls) formed the superstructure; little masonry rubble was found in the vicinity of the site, suggestive either that the superstructure was of a different material, or that spoliation had been thorough. Regarding the roof, significant quantities of stone roof tiles were found in the eastern half of the site, but with ceramic *tegulae* and *imbrices* found across the whole building.[180]

Turning now to Building A, the excavators identify three main phases of construction. Phase 1 saw the building in the early 2nd century of a c. 22.7 m by 11.5 m "aisled barn" of "rough but well-built masonry" with timber internal partitions.[181] Whether the external walls were entirely of masonry or were only foundations or dwarf walls with a timber framed superstructure was again not apparent in excavation. The second phase of construction saw the demolition of the original building in the late 2nd century, and its replacement by a larger one, c. 27.4 m by 12.4 m, on a rubble stone platform, perhaps because the original structure had subsided into the damp ground. It is described as having been built in better masonry, and was divided into eight rooms with one long corridor along the east side. The largest room had a rubble floor and a hearth in one corner with evidence of lead working, whilst the second largest room contained a raised floor on stone sleeper walls, resembling a granary; painted wall plaster suggested some domestic use alongside these productive functions.

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[180] Brodribb *et al.* (2005) 108.

[181] Brodribb *et al.* (2005) 4.

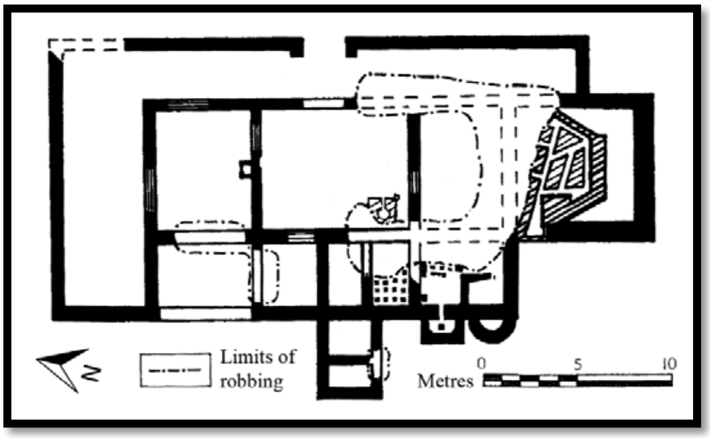

Figure 2. 4: Plan of Period 3b of Building A at Shakenoak Villa (After Brodribb et al. 2005 Fig. 1.4.)

Phase 3 again saw the demolition of the building, between AD 240 and 270, and the construction of another new structure with dimensions of c. 28.5 m by 14.7 m (roughly at the same time as the demolition of Building B, perhaps indicating the transformation of this previously productive site into the main high status domestic structure on the estate) Fig. 2.4). This building contained 10 rooms in its first phase, and up to 20 by the second half of the 4th century, including a suite of baths on the west side of the building and a stone-cut hypocaust in the southern end of the building. The central rooms of the building were adjudged to have had clerestory windows, given the fact that they were entirely internal, and would thus have had no natural light without these.

The building technique and materials for Building A are not described in such great detail, although the description of Building B, which is fuller, does note the similarity between it and the construction of Building A; again the structure has 60 – 75 cm thick walls of dressed-stone-faced mortared rubble, with facing stone of 15 – 25 cm face dimensions.[182] The dressed stone used for facing all periods of Building A, as for Building B, was judged to be of a local oolite of uncertain origin.[183] A reused pilaster, perhaps having come from Building B, is identified as being of Taynton Stone from the vicinity of Burford, roughly 10

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[182] Brodribb *et al.* (2005) 9-10; 80.
[183] Brodribb *et al.* (2005) 80.

km away via Akeman Street.[184] A large number of stone roof tiles were recovered, the majority of a pentagonal shape, and many with nails still present; some had been broken in antiquity at the nail-hole and had a new one chipped through. The tiles were identified as being almost certainly of Stonesfield Slate, extracted c. 5 km from Shakenoak via Akeman Street. CBM was present in the form of a large number of *tegulae* and *imbrices*, particularly in the levels of the Periods 1 and 2 buildings, while bricks for the hypocaust were also found, together with significant quantities of flue tile.[185] Several thousand tesserae were also recovered, including some of White Chalk, possibly from the Chilterns.[186]

2.4.6. Patterns

On the whole it seems reasonable to state that the majority of Roman buildings excavated in Oxfordshire were relatively simple post-built structures, with post-holes almost ubiquitous across all Roman sites in the county. Of course these are generally only discussed in brief, their ephemeral nature causing significant difficulty interpreting building layouts and construction techniques. Such construction might be seen as showing little development of vernacular construction types from the Iron Age into the Roman period in this region, although the greater frequency of rectangular structures at least suggests some alteration of building styles. Beamslot construction was also reasonably common across the county, indicative of timber-framing techniques, and thus uptake of Roman technology and techniques of timber construction in some instances.

Earth mass walling is a technique suggested on a number of occasions for sites in the Upper Thames Valley, including at Alchester and Dorchester, as discussed above. Whilst physical evidence is again slim for this construction technique, enough suggestive remains

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[184] Brodribb *et al.* (2005) 19.
[185] Brodribb *et al.* (2005) 21.
[186] Brodribb *et al.* (2005) 20.

have been discovered, and this, combined with the fact that it has been postulated for Iron Age as well as Roman structures in Oxfordshire, offers the possibility that it was a common vernacular construction technique in the region through these periods.[187]

Masonry footings were seen on at least 33 of the 131 Roman sites in Oxfordshire. These were seldom more than foundation deposits, or the first few courses of a wall footing, attesting primarily to the high degree of spoliation of stone building material. It is however not unlikely that only a proportion of all of these stone-footed buildings were carried to the eaves in stone. Whilst many of the masonry footings for which dimensions are given have widths of 0.6 m and upwards, frequently noted as therefore being substantial enough to support stone walls even of two storeys, such a judgement often remains only a *possibility*, with no positive evidence attesting to the *probability* of this construction technique.

Interestingly, stone use is not solely confined to the most prestigious of structures, with buildings on some relatively minor rural settlements as well as functional rather than domestic buildings on higher status sites demonstrating the use of the material.[188] Perhaps then this speaks not of the high status of stone structures *per se*, but of the extra resources and connections required in order to make use of the material in any quantity if it was not immediately available: in other words a certain economic threshold needed to be reached in order to gain access to it, and this is an idea which will be discussed more in Chapters 5, 6, and 7.

Turning now to the question of roofs, ceramic and stone roofing material was seen across many sites, although always only in relatively small quantities, speaking of highly

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[187] Allen, Miles, and Palmer (1984); Keevil and Booth (1997) 43; Booth, Evans, and Hillier (2002) 436.

[188] E.g. in the well-house at Barton Court Farm: Miles (1986) 14; in the "tower granary" at Denchworth Road, Wantage: Barber and Holbrook (2001); in the functional (granary and workshop) early phases of Building A at Shakenoak: Brodribb *et al.* (2005) 4; or in the "village" at Gill Mill, Ducklington: Booth *et al.* (forthcoming).

significant levels of spoliation. Stone roof tile seemed to be used on some sites even when stone walls did not seem to be present, such as in Building 2 at Denchworth Road, Wantage: this structure was seen as having been timber-framed, founded on post-pads and sleeper beams, possibly with wattle and daub walls, but a stone roof.[189] Why stone roofing material seems to see a wider distribution than stone walling material will be discussed further below (Chapter 6). Oxfordshire is blessed with at least two excellent stone lithologies for roofing, in the thinner facies of the Forest Marble Formation and the notable Stonesfield Slate, both discussed further in Chapter 5.5.1. Apparently there was a relatively ready supply of ceramic tiles across Roman Oxfordshire, although these have not yet seen enough study to enable a broad discussion of possible sources. A close reading of the evidence reveals an interesting, and perhaps unexpected feature of Oxfordshire's Roman structures: it was not uncommon to see in an excavation report the fact that both ceramic and stone roof tiles were found on the site. Shakenoak Villa and Barton Court Farm are both examples of this.[190] Two possibilities emerge. This could reflect a chronological development, and it has been suggested before that stone roofing appeared and became more common towards the later part of the Roman period, with ceramic roofing more popular in the 1st and 2nd centuries AD; thus the ceramic and stone material could therefore illustrate the rebuilding of roofs in different materials.[191] However, as will be discussed below, it can be very difficult unpicking the chronology of scattered building material found in soil layers above the Roman habitation deposits. The second possibility is that we have to consider whether a building might have had a roof of different materials, perhaps with one part of ceramic, and another of stone. The recovery of, for example, stone tile especially from the eastern side of Building B at Shakenoak, but a mixture of ceramic and stone tile from across the rest of the site, certainly reflects at least differential

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[189] Barber and Holbrook (2001) 117-121.
[190] Miles (1986) 13; Brodribb *et al.* (2005) 19, 21, 108.
[191] Williams (1971a) 178-9.

taphonomic processes for the roofing material of the structure, but perhaps could point towards the use of different roofing material for different phases of construction.[192]

Regarding the deciphering of the chronology of construction techniques across the county, several faint patterns might be discerned. One, particularly for villa sites, is of a trend of increasing monumentalisation, the expansion of buildings, and the greater use of stone. Such a pattern can be seen at North Leigh Villa, Ditchley Villa, and Shakenoak Villa (in both Buildings A and B), for example, but also in less prestigious sites such as Barton Court Farm and at Denchworth Road, Wantage.[193] However, this may be apparent because any sites which saw a trend in the other direction, from more elaborate to less, may be harder to find on account of the removal of material for reuse elsewhere. Certainly in the town sites at least we see stone foundations, when used, appearing rather scant: at Dorchester, Asthall, and Alchester, the later buildings are seen with minimal or even no depth of foundation.[194]

With all of these observations of course we must question whether any apparent patterns are really the result of a historical reality, reflecting the true variation of construction in Roman Oxfordshire, or whether biases or flaws of data collection, in terms of differential site preservation, or weaknesses in the archaeological fieldwork methodologies have created, or at least influenced, these patterns. Key to all interpretation are the facts that stone and ceramic materials are far more likely to survive in the ground than timber or mud materials, and are far more likely to be recognised in excavation; at the same time they were also very attractive for reuse, and clearly were spoliated in highly significant quantities at most sites, from the Roman period onwards. We must therefore acknowledge

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[192] Brodribb *et al.* (2005) 108.

[193] Ditchley: Radford (1936) 39 and Fig. 9; North Leigh: Wilson (2004); Shakenoak: Brodribb *et al.* (2005) 4 and 80; Barton Court Farm: Miles (1986) 12-13; Denchworth Road: Barber and Holbrook (2001).

[194] Frere (1962) 121; Booth (1997) 154; Booth *et al.* (2001) 435.

that our archaeological record for buildings is extremely complex, and allowance must always be made for the difficulties of interpreting such an incomplete sample.

2.5 Building Reconstructions

Creating theoretical reconstructions of Roman buildings is a useful activity. Three-dimensional representation serves as a powerful educational aid, adding man-made height to our consideration of Roman landscapes and allowing us to better consider the appearance and sensations of urban spaces as viewed from the street. They also allow us to consider the interior spaces of Roman built environments, and with that issues such as lighting and decoration. Finally, and most importantly here, three-dimensional reconstructions allow us to consider the range and quantities of materials needed for a construction project.

The art of reconstructing archaeological buildings, however, is fraught with pitfalls. One of the most prolific writers on the subject for the Roman period in Britain is David Neal, who in 1995 wrote that “few excavators attempted to make reconstruction drawings of their buildings, either because they rarely considered the superstructure, or out of caution should their work be criticised for being a flight of fancy.”[195] One only has to look at the criticism of de la Bedoyere’s work to see that Neal was right: de la Bedoyere produces some beautiful illustrations, but the relationship between the archaeological evidence and the reconstructed buildings has been questioned.[196]

Avoiding “flights of fancy” can be challenging, not least because the surviving evidence is often so patchy. Britain is generally lacking in standing Roman building remains which might provide useful analogy to assist in building reconstructions. Wall-footings and the rare survivals of wall and roof collapses noted above provide our best sources, but are still

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[195] Neal (1995) 33.

[196] De la Bedoyere (1991), reviewed by Zienkiewicz (1992).

severely limiting. This might be compared to the world of medieval building reconstructions, where practitioners are helped by the good survival of other, analogous structures, and so the techniques of construction, whether utilising a cruck system or a post and truss system, for example, can be understood from a combination of the archaeological remains together with numerous surviving examples of the techniques.[197] Standing-building survey of surviving structures allows determination of timber spacing and scantlings, i.e. the dimensions of timbers, crucial details for estimating material quantities needed, but ones which are often lacking for Roman structures. The opportunities for study that surviving structures of these centuries permit have even led to the development of equations for calculating the number of trees needed for such structures, considering the type and size of tree available, the varying techniques for converting it into useful timbers, and thus the acreage of woodland required.[198]

A crucial caveat of this exercise then is that results should not be seen as anything more than educated guesses. The most important outcome of these results is the suggestion of broad orders of magnitude for the quantities of materials used in the construction of several case study buildings. These do not constitute the suggestion of hard-and-fast values. Variation from these numbers is not only possible but fully expected, stemming from multiple factors. Specific sources of variation and uncertainty will be discussed for each construction technique below, but there are some that affect all. Firstly archaeological buildings are highly complex artefacts, and our evidence is only partial for the full details of the original superstructure, the possible phasing of is construction, mutation of the building over time, and complex variety in construction techniques. Secondly, these calculations are entirely dependent on the level of detail and accuracy of archaeological work, and the soundness of the excavators' interpretation of the building.

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[197] Brunskill (1994).

[198] Rackham (1972); Brunskill (1994); Varlow (2015).

2.5.1. Construction Techniques and Material Quantities

The initial part of this exercise is the determination of basic values for the quantities of material required per length, area, or volume of a particular construction technique.

2.5.1.1. Earth Construction: Cob and Pisé de Terre

Coming up with general rules for the relationship between wall volume and raw material weight for the earth construction techniques, including wattle and daub, is somewhat more difficult than when dealing with techniques which are assembled from discrete units such as stones or tiles. As with all of these theoretical calculations, significant variation is possible, namely on account of factors such as soil particle sizes (i.e. the proportion of clay to silt to sand within the soil), water content of the earth, the degree of compression, and the amount of temper or other constituents such as straw or gravel.

Nonetheless general figures for the degree of compression, and therefore the quantity of 'raw' material needed for construction in these techniques can be estimated. For cob construction, Quagliarini *et al.* give a figure of 1.2 m^3 of earth needed per m^3 of wall, and so we might take as a reasonable range 1.1 m^3 to 1.3 m^3.[199] For pisé de terre, the compression factor is rather higher, with Gallipoli *et al*. suggesting that 1 m^3 of walling would require c. 1.64 m^3 of uncompressed soil; to allow for variation, we might therefore allow a range of c. 1.5 m^3 to 1.8 m^3.[200]

2.5.1.2. Earth-Fast Posts and Timber Framing

Again significant variation will have existed in the manufacture and use of timber posts or frames, with variables including the precise type and number of timbers used, the lateral frequency of posts or studs, and the specific dimensions of all timbers. The combination of all of these variable factors makes generalised calculations difficult. The rare survival of

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[199] Quagliarini *et al.* (2010) 3306.

[200] Based on the density of rammed earth walling being somewhere in the region of 2000 kg/m^3, and uncompressed soil having a density of around 1200-1300 kg/m^3; Gallipoli *et al*. (2017).

water-logged timbers provides crucial evidence, as does the careful examination of post-holes: details such as the distances between them should be noted, and occasionally the section shape and dimensions of the post might be discernible if a post void remains.[201]

In this exercise, for timber-framed structures, calculations will be based on the simplest, essential components, consisting of baseplate timbers, studs, and a wall-plate at the top.

Through a combination of modern and medieval analogy, combined with the surviving Roman evidence, the following generalisations can be made. Regarding wood type, oak seems to have been the most commonly used for structural timber (either English Oak, *quercus robur*, or Sessile Oak, *quercus petraea*), both in the Romano-British evidence and from British medieval and post-medieval analogy.[202] The density of seasoned oak is about 720 kg/m^3.[203] A 40 – 120 year old oak (as those felled for the Cannon Street Roman timbers were) might be expected to provide reasonably straight timbers of up to c. 10 m in length, and a maximum of c. 1 m in diameter. Regarding conversion method (i.e. the way in which a felled tree was turned into useful construction components), nearly all methods were possible. However, of the 28 water-logged Roman timbers analysed by Nayling and Goodburn from Cannon Street, London, 17 (60.7 %) were boxed heart conversions, i.e. simply squared whole logs., 7 (25 %) were boxed halved, i.e. squared from half a log, and four were quarter or smaller fractions boxed (*cf.* Fig. 2.8).[204]

Looking at dimensions of timbers, the above-mentioned Cannon Street baseplate had sides of c. 150 – 300 mm.[205] Studs were spaced at c. 1 m intervals, and the studs themselves had c. 80 to 160 mm side lengths and were 2 to 2.5 m tall.[206] The wall-plate beams were of much the same dimensions as the baseplate. Shirley uses dimensions of 250 by 150 mm for

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[201] Goodburn (1991); Shirley (1996) 119.
[202] Rackham (1990); Goodburn (1991) 188; Schofield (1991) 10.
[203] Bates (2014) 30.
[204] Goodburn (1991) 187.
[205] Goodburn (1991) 200.
[206] Goodburn (1991) 200.

wall-plates and 150 by 200 mm for posts/studs in her reconstruction calculations for the Inchtuthil fortress.[207] Schofield collects medieval building contracts and laws, providing evidence from 14th-, 15th-, and 16th-century London for the dimensions of timbers. From three building contracts dating to 1369, 1383, and 1532, we learn of baseplates (or sill beams) with sections of 150 – 180 mm by 250 – 300 mm, studs with sections of 230 – 300 mm by 300 – 350 mm, and wall plates with sections of 200 by 250 mm.[208]

From these figures, for a basic, single-storey timber-framed structure, we might therefore offer general calculations for timber requirements, both in terms of weight, and in terms of trees required. An average metre of external wall requires a baseplate of c. 0.04 – 0.05 m^3, a 2 – 2.5 m tall stud totalling c. 0.02 – 0.04 m^3, and a wall-plate again of c. 0.04 – 0.05 m^3. If this frame sat on top of a masonry foundation we might expect the studs to be of just under half the height presumed here, making their wood requirement c. 0.01 – 0.02 m^3. This makes the total timber requirement for this notional simple frame of 0.10 – 0.14 m^3 per metre of length if 2 – 2.5 m in height, or 0.09 – 0.12 m^3 per metre of length if sat on masonry footings and so only 1 – 1.25 m tall. A 5 metre by 10 metre rectangular building of around 2 m height would therefore require c. 0.10 to 0.14 x 30 = 3.0 to 4.2 m^3 of timber for the frame, weighing 2.2 – 3.0 tonnes, and requiring, if baseplate and wall-plate timbers were made using boxed heart conversion, and studs using halved boxed conversion, somewhere in the region of 10 – 15 mature oak trees.

Added to this total would be any strengthening timbers such as struts and bracings (although Shirley estimates that these represent only c. 4 % of the total weight of the frame), and partition members (c. 6 % by weight of the total frame).[209] More significant

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[207] Shirley (1996) 119.
[208] Schofield (1991) 12.
[209] Shirley (1996) 120.

is the material for the infilling or cladding of the walls. This might have comprised wattle and daub, or timber planking ("weatherboarding").

For wattle and daub construction again we must allow for highly significant variation in material quantities, and it is relatively difficult to find quantified material costs for its production. The reconstructed Pimperne House at Butser Ancient Farm is one of very few sources: for the 40.5 m of circumference of the 12.9 m diameter roundhouse, with the wall being 1.5 m high, c. 10 tonnes of clay was used for daub, i.e. c. 250 kg per 1 x 1.5 m section, and Reynolds states that c. 0.5 ha of hazel coppice was needed for the wattle.[210] Durham states that a typical crop from 0.4 ha of well-managed hazel coppice might yield some 10,000 rods; comparing this figure to the Pimperne House construction gives a figure of c. 300 rods per 1 m long, 1.5 m tall section of wall.[211]

If timber planking is used to infill the timber frame, oak or perhaps elm would probably be the wood of choice.[212] As a suggestion we can use those found at the Courage Brewery site, Southwark, discussed above, measuring 35 – 38 mm thick and 250-400 mm wide.[213] To cover a 1 m length of wall, 2 – 2.5 m in height, would therefore require between 5 and 10 horizontal planks, equalling 0.07 – 0.10 m^3 of wood, weighing 50 – 72 kg per metre. Our notional 5 metre by 10 metre building would therefore require 1500 – 2160 kg of oak timber planking, minus any openings such as doors or windows. Calculating the number of trees this might require is slightly more difficult, due to the more complex conversions possible for producing planks, including quartered conversion, through and through conversion, or tangential conversion (Fig. 2.5).

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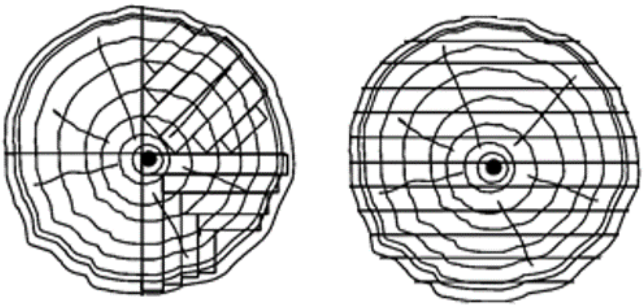
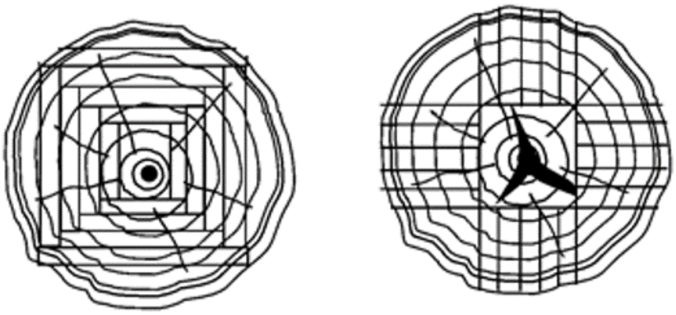
[210] Reynolds (1979).
[211] Durham (1956) 5.
[212] Schofield (1991) 10; Brigham *et al.* (1995) 33.
[213] Brigham *et al.* (1995)



Quartered Conversion

Plain Conversion



Tangential Conversion

Box Heart Conversion

Figure 2. 5: Timber conversion techniques (after Malthouse 2009).

2.5.1.3. Faced Mortared Rubble

One could examine any number of Roman masonry walls and arrive at a different answer each time for how much aggregate and mortar were used in their construction. Variation comes from the particular details of how the mortared rubble is laid, the facing material used, the sizes and shapes of the masonry aggregate, and simply whether the builder is prone to, or decides to, use more or less mortar. DeLaine discusses many of the issues inherent in calculating work rates and material quantities for masonry construction, and provides costed man-day calculations for different construction and facing techniques for a standard 12 m stretch, 3 m tall, 0.59 m wide wall, the facing and core volume calculations based on case studies from Ostia.[214] The example considering mortared rubble in tufa, based on the Casette-tipo, is most pertinent for our examination of standard building

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[214] DeLaine (2001) Appendix A.

practices in Roman Britain. In DeLaine's calculations the wall is divided into figures for its facing and for its core, the 12 m by 3 m stretch having a total volume of 5.47 m^3 of stone facing material in 0.07 x 0.09 x 0.12 m pieces, a total volume of 9.55 m^3 of core rubble in 0.07 x 0.07 x 0.11 m pieces, and a total volume of 6.22 m^3 of mortar, made up of 5.83 m^3 of pozzolana sand and 0.78 m^3 of quicklime.[215] Per 1 m^3 of wall would therefore require 0.26 m^3 of facing stone, 0.45 m^3 of core rubble, and 0.29 m^3 of mortar, made from 0.03 m^3 of quicklime (c. 45 kg) and 0.27 m^3 of sand (c. 400 kg).

Stone density of course varies by type and moisture content, but for the Jurassic limestones of Oxfordshire we might consider values of between 2.5 and 2.8 tonnes per m^3 to be reasonable estimates, with nearly all sedimentary rocks falling between 2 and 3 tonnes per m^3, whether water-saturated or dry.[216]

2.5.1.6. Roof Support

As with timber-framing, it is difficult, if not impossible, to generalise about the dimensions of roofing timbers, whose scantlings were scalable to the size of the building. Schofield's medieval building contracts record dimensions of 175 by 200 mm for principal rafters, 125 by 150 mm for common rafters, and 150 by 200 mm for tiebeams.[217] Shirley uses a figure of 250 by 300 mm for the tiebeams and principal rafters at Inchtuthil, based on "traditional rules of thumb," acknowledging that this is a plausible dimension, rather than "correct."[218] Common rafter spacing might typically be between 0.4 and 1 m, with trusses and principal rafters every 2.5 – 5 m.[219] Shirley estimates that the truss components make up roughly half of the total timber requirement of the roof, and a quarter of all timbers.[220]

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[215] DeLaine (2001) 247.
[216] Manger (1963).
[217] Schofield (1991) 12.
[218] Shirley (1996) 119.
[219] Shirley (1996) 113.
[220] Shirley (1996) 120.

Building the same simple 5 metre by 10 metre rectangular building posited above, with a 20° trussed roof, would therefore require: one ridge board (11 metres long, to allow 0.5 m overhang, with section, say, 150 mm square); trusses at each end and one in the middle, each formed of two principal rafters (c. 3.2 m long, to allow a 0.5 m overhang, and with section 250 by 300 mm), one tie beam (5 m long and 250 by 300 mm in section), and one king post (c. 1.1 m long and 200 by 200 mm in section); and 15 pairs of common rafters at 0.6 m spacing (c. 3.2 m long and 125 by 150 mm in section). This totals (Ridge: 0.25 m^3) + (Trusses: 3 * 0.90 m^3) + (Paired common rafters: 15 * 0.12 m^3) = just over 3 m^3 of timber, fitting well with Shirley's note that roof timbers would make up roughly half of all building timbers.[221]

2.5.1.4. Roofing

As noted above, ceramic or stone tiles are the most frequently attested roofing methods from Roman Britain, although this fact is heavily influenced by the durability of these materials: thatch, shingles, and turf are also likely to have been used.

Beginning firstly with ceramic roofing, problems are caused in these calculations by the fact that whole *tegulae* or *imbrices* are seldom found in the Romano-British archaeological record (see below, Ch. 3.1.1.). Tile size could vary significantly, as shown by a relatively small *tegula* found at Piddington measuring 310 mm by 270 mm, up to large *tegulae* from Silchester measuring 570 mm by 480 mm. From an assemblage of 615 complete Romano-British *tegulae* Brodribb quotes the average length to be 430 mm and width to be 330 mm, and flanges 50 mm high; Warry uses as an average 400 mm by 300 mm, with 50 mm high flanges and a 20 mm thick bed.[222] Both Brodribb and Warry calculate that on average 11 *tegulae* were needed to cover about 1 m^2 of floor in a building, taking into account the

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[221] Shirley (1996) 120.

[222] Brodribb (1987) 12 and Appendix 1; Warry (2012) 52.

overlaps between tiles and the pitch of the roof, generally between 20 and 30 degrees.[223] Each of those 11 *tegulae* would have a paired *imbrex*, except at the edge of a roof. Brodribb gives average *imbrex* dimensions of 398 mm long (ranging from 360 mm – 510 mm), 172 mm wide at the wider end (a range of 130 mm – 220 mm), 135 mm wide at the narrower end, and an average height of 93 mm at the wider end, 73 mm at the narrower end.[224] Average thickness he cites as 20 mm, with a range from 14 mm to 30 mm.

The approximate range of weights for *tegulae* would be between 6 and 12 kg, and between 2.5 and 3.6 kg for *imbrices*, based on Brodribb's reporting of whole tiles from Beauport Park and Caerleon.[225] Using these values we can come up with a general expression for the material requirement for roofing 1 m^2 of floor area: 11 *tegulae* plus 11 *imbrices* would weigh between 93.5 kg and 171.6 kg. To this we might further add the weight of any ridge tiles, antefixes, mortar, or nails used.

Roman stone roofing materials have rarely been studied or described in detail, and so it is difficult to pull together general information on their dimensions and weight. In addition, if medieval stone roofing practice is of relevance, multiple different sizes of stone are used: width is to some roofers entirely irrelevant, but tile length is carefully judged in order to lay diminishing courses from eaves to the ridge. It is generally acknowledged by modern practitioners using stones such as those found in the Cotswolds that steeper roof pitches are better for throwing off the rain, and 47° up to 65° is common in standing medieval buildings with stone roofs in that region. As a general guide, based on modern building

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[223] Rook (1979) 295; Brodribb (1987) 12; Warry (2012) 52.

[224] Brodribb (1987) 26.

[225] Brodribb (1987) 11-12; Mills (2017) pers. comm. Note that Brodribb persistently miscalculates when converting between lbs and kg. The average weight of 41 complete *tegulae* from Beauport Park is quoted as "13.6 lbs (29.98 kg)," which should presumably read 6.17 kg; for *imbrices* from the same site he quotes "5.6 lbs (12.34 kg)," which should presumably read 2.54 kg. For the Caerleon tiles he quotes *tegula* weight as "25 lbs (55 kg)," presumably intended to read 11.33 kg, and *imbrex* weight as "8 lbs (17.6 kg)," presumably intended to read 3.63 kg.

manuals, a single stone tile might weigh between 1.5 and 2.5 kg, and 1 m^3 of stone roofing might require something in the region of 40 to 60 tiles, weighing between 50 and 100 kg.

For thatched roofs, variation in the quantity of straw or reed needed for thatching a roof would depend on how thickly it was layered. Green states that a 7 m diameter roundhouse would have needed c. 1 tonne of straw, and a 15 m diameter roundhouse would have used c. 15 tonnes.[226] The 12.9 m diameter reconstructed Pimperne House used c. 12 tonnes of straw.[227] The floor area of the building is c. 135 m^2, which allows us to calculate that every 1 m^2 of roundhouse floor requires c. 90 kg of straw. However, this figure is specifically applicable to round buildings with conical roofs, not to rectangular roofs; in order to obtain a more useful figure for our calculations, we can calculate from the Pimperne House a standard figure for the quantity of thatch required per m^2 of roof. Given a 45° pitch and a 6.45 m radius for the Pimperne House, it is possible to work out using trigonometry that the sloping sides of the roof are therefore 16.85 m long, and using the formula πrl for calculating the surface area of a cone, the Pimperne House roof therefore has an area of 341.4 m^2. From this we can calculate that each 1 m^2 of roof area required c. 35 kg of straw, a number that accords very well with a figure given by the Somerset Vernacular Building Research Group of approximately 34 kg/m^3 of thatch.[228] Shirley gives a figure of 75 tonnes of thatch required to roof, at 300 mm thickness, the 450 m^2 of roof area of the Tribune's House I at Inchtuthil, which works out at a rather larger 167 kg of thatch per m^2 of roof, and so this number should perhaps be treated with caution.[229]

2.5.2. Theoretical Reconstructions and Material Quantities

Using examples from sites described above, broad scales of material use for different structures, built using different construction techniques, can be calculated. Note that for

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[226] Green (2012) 202.

[227] Reynolds (1979).

[228] Url = http://svbrg.org.uk/roofcoverings.php (Accessed 22/10/17).

[229] Shirley (1996) 118.

these reconstructions the plans in published excavation reports have been simplified slightly for clarity, and to move the focus onto the dimensions of structural parts of the building rather than every last excavated detail. The plans should be understood to be hypothetical building layouts, heavily informed by the archaeology.

2.5.2.1. Dorchester on Thames Building 1.i, 4th Century AD

Beginning with the building uncovered by Frere at Dorchester in the 1960s, calculating material quantities for a hypothesised structure with stone footings, a timber frame with wattle and daub in-filling, and a ceramic roof, the following can be calculated. Based on the plan (Fig. 2.4), the structure will require stone for the external walls, whose volume can be calculated from their lengths (12 m and 6 m for the long and short sides respectively, their thickness of 0.7 m, and an estimated height of 1 m: this yields a volume of 25.2 m^3. From the photograph of the construction techniques we can see that the wall appears to have a rough facing, perhaps c. 10 – 15 cm thick, which compares with DeLaine's 12 cm thick facing from Casette-tipo in Ostia. Using the figures calculated in that exercise, of 0.26 m^3 of facing stone, 0.45 m^3 of core rubble, and 0.29 m^3 of mortar per m^3 of wall, we can estimate a total volume 17.89 m^3 of stone and 7.31 m^3 of mortar required just for that 1 m high external wall footing. Using our typical values for the density of limestones this equates to between 42.5 and 47.6 tonnes of stone.

Above the stone footing a timber frame with wattle and daub infilling is hypothesised. Using the figures presented above of 0.09 – 0.13 m^3 timber per metre of length (using the broadest range including a 1 m tall superstructure up to a 2.5 m tall superstructure), this building, with 36 m of external wall length, would therefore have required 3.24 – 4.68 m^3 of timber, weighing 2.33 – 3.37 tonnes. For the wattle and daub this structure would require somewhere over 9000 hazel rods, or the annual crop from c. 0.4 ha of hazel coppice, plus around 10 tonnes of clay or earth for daub.

For the roof, hypothesising a trussed roof similar to that imagined above with a 20° pitch, the following components would be required: a ridge board (13 m long, 150 mm square in section); trusses at each end and two in between at 4 m spacing formed of a pair of principal rafters (3.75 m long, 250 by 300 mm in section), one tie beam (6 m long and 250 by 300 mm in section), and one king post (1.2 m long and 200 by 200 mm in section); and 17 pairs of common rafters at 0.6 m spacing (3.75 m long, 125 by 150 mm in section). This totals (Ridge: 0.29 m^3) + (Trusses: 4 x (0.56 + 0.45 + 0.05)) + (Paired common rafters: 17 x 0.14) = 6.9 m^3 of timber, weighing roughly 5 tonnes. The tiled roof for this 72 m^2 building, with a 0.5 m overhang on all sides (making the area requiring roofing 91 m^2), assuming roughly 11 *tegulae* and 11 *imbrices* per 1 m^2, plus *imbrices* for the ridge, would have required just over 1000 *tegulae* and c. 1040 *imbrices*, weighing between 8.6 and 15.75 tonnes.

Dorchester Frere Building 1.i.			
Floor area	72 m^2		
Roof area	78 m^2		
Dwarf (1 m tall) external mortared rubble wall			
	Total volume	25.2 m^3	
	Stone	17.89 m^3	42.5 - 47.6 tonnes
	Mortar	7.31 m^3	0.75 tonnes quicklime
Timber in superstructure frame			
	Timber	3.24 – 4.68 m^3	2.33 – 3.37 tonnes
Wattle and daub in superstructure			
	Wattles	9000 hazel rods	c. 2 tonnes, 0.4 ha of coppice
	Daub	c. 8.3 m^3	c. 10 tonnes
Roof			
	Timber roof support	6.9 m^3	5 tonnes
	CBM roof	1000 tegulae and 1040 imbrices	8.6 - 15.75 tonnes

Table 2. 3: Hypothesised building material requirements for Dorchester Frere Building 1.i.

2.5.2.2. Shakenoak Building A Period 3, 4th Century AD

Turning now to the rather more prestigious structure of Building A, at Shakenoak, and in particular its Period 3 'villa' form, allows the calculation of material quantities for a more complex building. Going by the excavator's reconstruction drawing of the villa (Fig 2.7), the structural parameters used here will work from the assumption that the walls were taken up from foundations to the eaves entirely in limestone mortared rubble, with a clerestory structure, built with a timber frame and wattle and daub, allowing light into the central rooms, and presumably supported by those main partition walls forming the old core of the building; the roof comprised a hipped lower roof covering the corridor running around the northern half of the villa, and a gable ended upper roof covering the clerestory; both are depicted covered with stone tiles. The projecting rooms appended in Period 3b, and taken by the excavators to represent baths, reconstructed with vaulted concrete roofs, are not included in the calculations here.

Beginning with the mortared rubble external walls, these are recorded as being of 0.6-0.75 m thick; foundation depth is not given, so a suggestion of 0.3 – 0.5 m is made; from the image we might assume these external walls to be around 2 m tall around the northern half of the villa, and c. 4.4 m (assuming a roof pitch of 30° over the 3.9 m wide corridor, equating to a 2.43 m rise) at the southern end where the covered corridor is not present and in the walls of the central four rooms covered with the clerestory roof. There are 74.9 m of 2 m walls and 69.4 m of the 4.4 m walls. This corresponds to volumes of 103.4 – 140.4 m^3 for the shorter walls (the variation accounting for the range of foundation depth and wall thickness given above) and 195.7 – 255.0 m^3 for the taller walls, a total volume of 299 – 395 m^3. As before, using the figures DeLaine gives for stone to mortar ratios in a faced mortared rubble wall (in that case 0.6 m wide, comparable to Shakenoak; the facing stone dimensions for Shakenoak are not given, so a figure akin to DeLaine's 120 mm thick facing is accepted as reasonable), this equates to c. 212 – 280 m^3, or 530 – 787 tonnes of limestone rubble, plus 87 – 115 m^3 of mortar, made from 13.5 – 17.8 tonnes of quicklime, for the combined external and internal structural walls. Openings, including the c. 4 m wide doorway interpreted as a barn entrance on the west side of the building, would reduce the stone requirement by c. 7 – 10 tonnes.

For the timber frame and wattle and daub of this upper structure, a figure of 1.5 m of height is taken, running for a perimeter of 69.4 m. In terms of timber, this would therefore require c. 5.6 - 6 m^3 for the horizontal plates and 0.7 – 1.4 m^3 for upright studs, a total of 6.3 – 7.4 m^3, or 4.5 – 5.3 tonnes of oak. For the wattle and daub infilling, at the requirement of 300 hazel rods per 1 m by 1.5 m panel, over 20,000 rods would be needed, or the annual product from around 1 ha of coppice. In terms of earth, at 250 kg per 1 m by 1.5 m panel, this would equate to 17.4 tonnes. A covering of weatherboards would be rather less heavy, but presumably rather more expensive, using a more valuable resource requiring significantly more processing: using 35 mm thick, 300 mm wide planks would entail the use of 3.6 m^3 of timber, or c. 2.6 tonnes. This figure would be reduced somewhat by the clerestory windows, perhaps by as much as 1/5th, taking the total to 2.9 m^3 or 2.1 tonnes.

Regarding the roof, two calculations need to be made for the lower, hipped roof and upper, gable truss. For the lower, hipped roof, with no need for a ridge beam or truss given the narrow span (rafters presumably attaching to the baseplate of the clerestory frame on top of the tall internal wall), and with common rafters at 0.6 m spacing, the following would be required: 93 common rafters of 4.85 m length and 125 by 150 mm section; 2 hip rafters of 6.4 m length and 250 by 300 mm section; and 24 “creeper rafters” of variable lengths for the hipped corners totalling 58.8 m of 125 by 150 mm timber. This adds up to 8.5 m^3 of common rafters, 1 m^3 of hip rafters, and 1.1 m^3 of creeper rafters, totalling 10.6 m^3 of timber, or 7.6 tonnes.

For the gable roof, with a span of 7.8 m, a truss system would be required. Using a pitch of 30°, and running for 26.8 m, the timber supports for this roof would therefore entail: a ridge beam 27.4 m long and 150 mm square in section; 6 trusses at 5.3 m spacing, made from a pair of principal rafters (4.9 m long, 250 by 300 mm in section), one tie beam (7.8 m long and 250 by 300 mm in section), and one king post (2.4 m long and 200 by 200 mm in section); and 32 pairs of common rafters at 0.8 m spacing (4.9 m long, 125 by 150 mm in section). This adds up to (Ridge: 0.62 m^3) + (Trusses: 6 x (0.74 + 0.59 + 0.1)) + (Paired common rafters: 32 x 0.18) = 15 m^3 of timber, weighing roughly 11 tonnes.

For the roof covering of stone tiles, we can calculate from the floor area of 430 m^2, with a pitch of 30°, the roof area would have been c. 500 m^2. As stated earlier, allowing for the significant variation seen in tile-stone size and weight, we might expect this roof to have required somewhere in the region of 20,000 to 30,000 tiles, weighing 25 to 50 tonnes.

Shakenoak Building A Period 3			
Floor area	c. 430 m^2		
Roof area	c. 500 m^2		
Structural mortared rubble walls			
	Total volume	299 – 395 m^3	
	Stone	212 – 280 m^3	530 – 787 tonnes
	Mortar	87 – 115 m^3	13.5 – 17.8 tonnes quicklime
Timber in clerestory frame			
	Timber	2.9 – 3.6 m^3	2.1 – 2.6 tonnes
	Wattle	20,000 rods	c. 5 tonnes, 1 ha of coppice
	Daub	14.5 m^3	17.4 tonnes
Roof			
	Timber roof support	25.6 m^3	18.6 tonnes
	Stone roof	20 – 30,000 tiles	25 – 50 tonnes

Table 2. 4: Hypothesised building material requirements for Shakenoak Building A Period 3.

2.5.2.3. Conclusions

In summary, the key aims of this section have been to illustrate the range of construction techniques available and used in the region, and to emphasise the sheer quantities of building materials required in construction. Whilst there is growing evidence for all materials and techniques, the more ephemeral methods, including timber and earth construction, still lag significantly behind in terms of our understanding of their use. It must surely be concluded that more consideration needs to be made of the possibility of their presence on archaeological sites, and more effort must be made to detect them. With regards to the question of material quantities, multiple caveats, extrapolations, and assumptions are acknowledged for the calculations given above. Nonetheless the broad scales of material use must be correct, and the highly significant numbers seen illustrate the importance of considering building techniques and building materials, as will be discussed further below.

3. Building Materials in Roman Britain

"Priscus, son of Toutius, stonemason, a tribesman of the Carnutes, to the goddess Sulis willingly and deservedly fulfilled his vow." – inscription from Bath, *RIB 149*

3.1. The Study of Ceramic and Stone Building Materials: A Case of Neglect?

Across both British and European scholarship the biases outlined above in the study of Roman buildings are both the result of, and have propagated, the focus on questions of architecture and artistic styles in preference to questions surrounding building materials and building processes. Certainly there have been attempts to redress this balance: major works such as Adam's *Roman building: materials and techniques*, DeLaine's *The Baths of Caracalla: A study in the design, construction, and economics of large-scale building projects in imperial Rome*, and Lancaster's *Concrete vaulted construction: innovations in context* have drawn the focus far more towards those latter two subject areas.[230] More recently still the international *Arqueología de la construcción* workshops, originating at the Archaeological Institute of Merida in 2007, followed by conferences at Siena (2008), Paris (2010), Padua (2012), and Oxford (2015), and published in the *Anejos de Archivo Español de Arqueología*, have given rise to a steadily growing academic community asking questions about the materials, economics, logistics, technology, and processes of construction.[231] Two workshops on Roman brick, the first, on production, held in Rome (2014), the second, on brick's origins, in Padua and Genoa (2016), show a new focus of interest in precise, detailed analyses of this material. The ongoing ASMOSIA (Association for the Study of Marble and Other Stones in Antiquity) conferences with associated publications (more on these below), and a recent conference held in Tongeren, Belgium (2016), on "Roman

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[230] Adam (1994); DeLaine (1997); Lancaster (2005).

[231] Camporeale, Dessales and Pizzo (2008), (2010), (2012), (2014); DeLaine, Camporeale and Pizzo (2017).

ornamental stones in north-western Europe" offer growing opportunities for the intensification of study of building materials.[232]

Despite these examples however, the detailed study of building material still tends not to be high in the priorities of many excavators or researchers, and thus it is still a developing field. Building materials offer many impediments to their study, particularly in comparison with some other artefact types. Too often this difficulty leads to many excavation methodologies and reports ignoring the fact that construction materials are not truly an artefact in themselves, but integral fragments of the much larger artefact: a building. A key argument of this thesis is that whilst analysing building materials in their own right is a necessity and an initial step following excavation, we should never lose sight of the fact that these materials, a single tile, or a lump of stone, were once part of a synthetic whole, brought together with many other tonnes of material to create a building. A paradigm shift is required, moving from studies treating these individual pieces, or individual material types, in isolation, to the regular synthesised analysis of all materials together. The conclusions drawn from the material types need to be integrated to explore what we can therefore learn about the whole building, its architecture and its construction, for which, after all, the materials were produced.

In this chapter we will examine the ways in which building materials have been studied, the difficulties that we face, and what more detailed, more synthetic studies of building materials might yield.

3.1.1. Missing Materials

The initial difficulty we face with any study of buildings in the Roman Empire is missing material: much of the building material which was originally used is not present in the

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[232] Laterizio Conference: Bukowiecki, Volpe and Wulf-Rheidt (2015); ASMOSIA: URL = http://asmosia.willamette.edu/ (accessed 11/11/2016); Tongeren conference: URL = http://www.hands.be/grm/index.php (accessed 11/11/2016).

immediate archaeological deposits around its site of use. In the intervening centuries since the end of occupation of many Roman buildings significant proportions of the total material involved in their construction have either decayed naturally, particularly in the case of organic or highly friable materials, or they have been reused, in the case of materials which could be 'spoliated' and efficiently put to a new purpose.[233] This forces any study either to accept and admit the limitations of being based on the relatively small proportions that are excavated, or to find an approach which considers the missing material, requiring both theoretical reconstructions and an exploration of those processes of reuse. In this survey stone and ceramic building materials are focused upon, these being those most reliably found on archaeological sites.

An initial step in understanding the remains we do have is to consider the nature of the assemblage. Types of building material assemblage from Roman sites might fall into four broad categories.

Firstly, we might find some part of a Roman building still standing in situ. This scenario is perhaps the most helpful, as in this case we are able to look at individual pieces of material still largely intact, as they were formed by the Roman workmen; further, each individual piece of material is directly associated with other materials in the context, be that other blocks of stone in a wall, for example, or the mortar binding them. The most impressive examples of this from Roman Britain include the "Old Work" basilica-cum-palaestra at Wroxeter, Shropshire, standing c. 7 m tall, or the recently excavated standing remains at Binchester, County Durham.[234] This direct association allows us to consider the actual process of construction much more closely, including questions such as whether material

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[233] Note that, after Munro (2010, p. 11), through the term "spoliation" there is intended no suggestion that the extraction of building materials from Roman sites by post-Roman populations amounts to a "violent theft" of cultural materials, as the etymology of the term might imply. The term is used here as a useful, neutral word to describe the process of the extraction, even "quarrying," of building material from a decaying or disused Roman building, and there is growing recognition that this was a highly skilled and economically very important activity; see below and Munro (forthcoming).

[234] Webster and Woodfield (1966); Ferris (2011).

was all acquired from the same source or was mixed, and the sequence in which the walls were built and how this was undertaken.[235]

Secondly, we might find building materials lying in situ where they collapsed, for example the gable end wall collapse from Redlands Farm, Northamptonshire, or the roof collapse at Beauport Park bathhouse, East Sussex.[236] Here again we possess individual pieces which are largely intact, and also still bear a physical relationship to other materials in the structure, offering us the ability to explore those lines of questioning mentioned above. Additionally, these collapses give us evidence of parts of buildings which often do not survive as assemblage type 1, including upper storeys and roofs.

Thirdly we might identify Roman building materials reused in more recent construction, such as medieval churches or houses.[237] In this case pieces may have been re-worked or altered, possibly removing the option of morphological analysis, and we do not know of the physical relationship between individual pieces of Roman building materials used in this way; whilst it is entirely plausible that all may have been extracted from a single Roman building, there could also be a mixture from multiple sites or structures, making insight into construction processes more difficult.

Fourthly our assemblage might come from secondary, mixed, non-structural deposits, for example in ditch or pit fills, or as general layers covering Roman sites. In this case building material is often present in small quantities, frequently fragmentary in nature, and representative of general dumps or accumulations of material deemed rubbish, not chosen for reuse. To offer some idea of just how fragmentary these assemblages often are, McComish notes that of the 8 tonnes, in some 36,000 sherds, of Roman CBM excavated by

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[235] *Cf.* for example the possibility of identifying the presence of separate workers in Trajan's Markets through identifying "pigs" in the brickwork (Lancaster 1998), or similarly in Allen (2012).
[236] Keevill (1996); Brodribb (1979).
[237] E.g. Parsons and Sutherland (2013).

York Archaeological Trust, over 60 % was so fragmentary to be of indeterminate form, and just 158 sherds had complete surviving length measurements and 246 had complete surviving breadth measurements.[238] With such a 'bitty,' fragmentary assemblage, our options for analysis are again highly limited, as morphological approaches are frequently obstructed by the incompleteness of pieces, and from such mixed deposits we are rarely able to identify whether the material comes from a single structure or multiple structures from within the vicinity.

"Spoliation" and reuse was a highly important process across much of the Empire in the later Roman and post Roman periods, and commonly resulted in assemblage scenarios three and four. The precise processes are very difficult to reconstruct, with the possibility of multiple 'events' occurring in the chaîne opératoire: a long history of building collapse, material reuse, further collapse, and multiple episodes of reworking or other recycling processes before final deposition, is entirely possible, and might create an assemblage which appears archaeologically much the same as material which had a short chain of the same processes.[239]

Reuse of building materials has grown as an important topic, particularly in the last decade, as can be seen for example with Barker's thesis on demolition and salvage of building materials in Rome, and Munro's on "Recycling the Roman Villa."[240] In Britain isolated examples of this type of study exist, including in a paper by Allen and Fulford on the reuse of stone from the Roman coastal forts between The Wash and northern Kent, Tim Eaton's exploration of stone reuse in the post-Roman period, and long-term research

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[238] McComish (2015) 8.
[239] Bernard *et al.* (2008).
[240] Munro (2010); Barker (2012).

by Everson, Parsons, and Sutherland on the reuse of Roman brick and stone in the Anglo Saxon Brixworth Church.[241]

Assemblage scenario one, although demonstrating the best preservation, still tends only to present us with material that was left behind following quarrying of the more easily extracted material around it; this means material is often taken from the parts of walls projecting above the ground, and which therefore required less effort to remove. The buried foundation needed significant work to extract, and so this is often the most common type of coherent masonry uncovered. Scenario two is rare, generally confined to rural sites where the spoliation of the fallen material was not undertaken for some reason, either because the material was rapidly made inaccessible, because it was not needed in that vicinity, or was uneconomical or unsuitable for use. Material from assemblage scenario 3 is difficult to recognise, and even harder to analyse if it still forms the matrix of standing buildings. Scenario four is perhaps the most frequently occurring archaeological situation, and is the source of most of the building materials in excavation archives. Very commonly the material in these assemblages is highly fragmentary, making analysis difficult.

3.1.2. Difficult Materials

Even with an intact assemblage, from a wall collapse for example, at first glance our analytical options, and the stories these can tell, appear limited. Morphological analyses of building material are difficult and perhaps not that informative, since building materials in the most part lack the obvious diversity and control of forms seen in other archaeological materials such as pottery. Those few morphologically interesting areas such as tile flanges or cutaways, or faced surfaces of stone, are even rarer in a fragmentary

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[241] Allen and Fulford (1999); Everson and Parsons (1979); Sutherland and Parsons (1984); Sutherland (1985); Parsons and Sutherland (2013); Eaton (2000).

assemblage which has been subjected to spoliation, and without related comparative material we are further limited in the conclusions which can be drawn. Analyses of CBM fabrics or stone geology require investment in expertise and analytical tools. With regard to traditional ceramic petrography by thin section analysis, there are significant questions which need to be answered concerning the difficulties of subjectivity, and the varying degrees of experience that all practitioners will have, possibly leading to divergent conclusions.[242] With regards to more modern or 'high-tech' methods, the integration of archaeological science into more traditional archaeological practice has been slow, with effective engagement between archaeological scientists and archaeologists often still lacking, resulting in something of an "us" and "them" divide.[243] Details of archaeometric methodologies and findings are usually difficult for non-scientists to follow, and it must be understood that there is no single infallible methodology for the archaeometric analysis of ceramic or stone.

In sum, this combination of factors has led to building materials being relatively rarely studied. At the very first stage of the process – excavation – it is often not even a given that building materials will be collected, but on some sites are just put straight onto the spoil heap. If material is collected, it is often not preserved, undergoing simple quantification before being re-deposited on site. Being bulky and thus expensive and difficult to handle, transport, process, and in particular store, it makes an unattractive investment for comprehensive analysis by archaeological projects, particularly when the possibility of gaining significant insight into the Roman world is seen as a scant hope, the material written off as uninteresting. As Warry remarks in the Acknowledgements of his work on *tegulae* in Roman Britain, when material is collected, it "languishes as a Cinderella artefact, unavoidably assigned to the darkest and least accessible parts of a curator's store and, by

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[242] *Cf.* Graham (2006) 31-34.
[243] Pollard and Bray (2007); Schrüfer -Kolb (2012); Pollard (2012).

some immutable law, always with the heaviest boxes on the highest shelves;" he states that regularly the museum curators he worked with told him that he was the only person ever to have examined their CBM collections.[244] It is clear then that the subject needs a re-evaluation and more work. The following section explores ways that ceramic and stone material have been studied in regions across the Empire, before focusing on the situation in Britain.

3.1.3. Ceramic Building Materials

The academic study of ceramic building material in some form or other has a history certainly going as far back as the 19th century. Throughout this time a range of different approaches to the material have been taken, and these might broadly be grouped into three main categories – 1. analysis of stamps or other markings; 2. analysis of fabric; 3. analysis of form.

1. The investigation of brick stamps was perhaps the earliest analytical technique deployed, brick stamps from Rome having been catalogued formally by Dressel in the late 19th century in a volume of the *Corpus Inscriptionum Latinarum*.[245] Interpretation of brick and tile stamps, as well as so-called "tally marks," signatures, and graffiti has continued to this day as a key tool in the study of CBM, and indeed for long periods this represented the only method used in the study of ceramic building material.

Following up on the work of Dressel, academics such as Bloch, Steinby, Helen, the volume edited by Bruun, and following that work by Graham, have updated and reinterpreted brick stamps from Rome, Ostia, and the Tiber Valley, using them to explore building chronologies and the relationships between landowners and brick producers.[246] However, Rome must be seen as something of a special case, with its huge demand for CBM and

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[244] Warry (2006) *Acknowledgements*.

[245] *CIL* XV.1.

[246] Bloch (1947), (1948), (1959); Steinby (1974); Helen (1975); Bruun (2005); Graham (2006).

imperial involvement in the trade. The recent workshops held in Rome and Padua demonstrated rich new work being undertaken on CBM from both Rome and elsewhere in the Empire, utilising stamps.[247] The same method has been used in Britain, where the 1970s in particular saw a relatively large number of published tile stamp studies.[248] Tile production involving the military has dominated research in the UK, understandably given the fact that military stamps are the most common, or at least the most easily interpreted, in this region. Such papers include Wright's on tile-making by the sixth and ninth legions, Brodribb's survey of the *Classis Britannica* stamps from the collapsed bathhouse roof at Beauport park, Wiseman's demonstration of the use of civilian contractors by military units, and Warry's investigation of the products of the kilns of the twentieth legion at Holt.[249] Not just military tiles were stamped however, and a series of papers by McWhirr, Viner, and Darvill analysed non-military stamps from the Cirencester region, mapping the distributions of the *LHF* and *TPF* stamp series, showing material probably made at the kiln site of Minety travelling as far as the sites of Old Sarum and Silchester, more than 70km distant.[250] Mills' recent survey stands out as a useful brief summary of the subject in Britain.[251]

This particular analytical method, using stamps, is popular because of the attractiveness of epigraphic sources, sometimes allowing explicit and direct comparisons with historical texts, and such markings sometimes aid the connection of material found in different locations without the need for evidence from petrographic analysis.[252] The nature of this method does however present problems for answering some broader questions about the manufacture and use of CBM. Stamps might be misleading if the dies or stamp legend are

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[247] Bukowiecki, Volpe and Wulf-Rheidt (2015); *cf.* Clement (2013).

[248] E.g. Wright (1976), (1978); Darvill (1979); Hassall (1979).

[249] Wright (1976), (1978); Brodribb (1979); Wiseman (1979); Warry (2010).

[250] McWhirr and Viner (1978); Darvill (1979); Darvill and McWhirr (1982).

[251] Mills (2013a).

[252] E.g. Graham (2006) 57, comparing tile stamp evidence from Rome with Varro *De Agr.* 1.2.22-3 and *Digest* book 8.

used on stamps produced in different places, or if the legend is misunderstood.[253] Not all CBM types were stamped: *tegulae* are the form most commonly marked in this way in Britain, but not every *tegula* bears a mark, and with the often fragmentary nature of finds of *tegulae*, not all pieces will be from the lower part of the upper surface of the *tegula* which was the most routinely stamped area. Thus attempts at measuring the incidence rate of stamping are severely flawed, unless we can be sure we have a 100% sample (e.g. a collapsed roof in situ, or a fully stacked kiln). Historically collected assemblages might potentially be biased by the preferential retention of stamped tiles over non-stamped, making the use of old assemblages in modern studies problematic. As mentioned above, in Britain, tiles produced by or for military units are perhaps more likely to be stamped than tile produced by other groups, e.g. "civilian" or "municipal" tileries.[254] This in itself means conclusions based on tile stamp analysis may not apply equally to all tile 'industries,' as significant organisational differences may well exist between military and non-military production. Indeed the dichotomy of "military" and "civilian" production has not been fully investigated, the potential crossover between the two being illustrated by Wiseman.[255] A final problem lies in the fact that, as in Rome with brick, stamping does not span the full chronology of tile production in Roman Britain, seeming to begin with Nero, and ending sometime in the mid-3rd C.[256]

2. The second approach to the study of tiles, fabric analysis, can itself be divided into a number of different practical methods, with the major techniques being simple hand specimen examination, binocular microscopy, thin section (or "petrographic") microscopy, and a wide array of chemical techniques.[257] These include X-ray fluorescence analysis, X-ray diffraction analysis, neutron activation analysis, inductively coupled

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[253] E.g. Bogaers (1977).

[254] Mills (2013a) 442.

[255] Wiseman (1979); c.f. Kurzmann (2005).

[256] Greenaway (1981); Warry (2010).

[257] E.g. Peacock (1977a); Darvill (1979); Betts and Foot (1994).

plasma mass spectrometry, and scanning electron microscopy.[258] Micro-textural approaches such as grain counting and measuring have also been used.[259]

The analysis of fabric is a technique that has been used extensively in the study of pottery, and nearly all of the principles of the method are directly transferable to the study of CBM.[260] In essence the method offers the opportunity for exploiting the geological signature of a tile in order to address questions of manufacturing processes, origin, and distribution. A fabric is defined as the physical characteristics of the fired ceramic object, and from it the geological raw materials, the actions of the maker, and the firing conditions might all be deduced.[261] In comparison to stamp analysis, tile fabric analysis has the advantage that any given CBM fragment can be analysed, no matter the nature or size of the piece. The technique has been shown to be very powerful when used in conjunction with stamp evidence, for example Peacock's 1977 paper showing *CLBR* stamped tiles to have been made on both sides of the channel, some made locally at the fleet's base in Boulogne, and some probably made of Fairlight Clay from the Sussex and Kent Weald.[262] Darvill's 1979 paper combines thin section microscopy with stamp analysis to demonstrate that there were at least two different fabrics which carried the *TPF* stamp, both most likely originating in the Cotswolds, but enlightening us to the potential for the existence of "itinerant" tile-makers, using the same stamp to mark tiles made at different production sites. [263] Similar conclusions have been drawn from analysis of relief-patterned tiles, with makers and their roller-dies used to make the characteristic impressions seeming to move and make use of different clay sources.[264] Itinerancy of producers would not necessarily

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[258] E.g. Meloni, Oddone *et al.* (2000); Finlay, McComish *et al.* (2012).
[259] Peacock (1977a).
[260] *Cf.* Orton, Tyers and Vince (1993).
[261] Orton, Tyers and Vince (1993) 67.
[262] Peacock (1977a).
[263] Darvill (1979).
[264] Johnston and Williams (1979).

have been proven if analyses had used only stamp evidence, and this further serves as a useful caution against assuming too much from just the stamps.

These fabric analysis methods do also have problems however. There are significant difficulties inherent in matching a fabric to a source, no matter how precisely it is characterised. The ideal scenario might be a kiln site with associated wasters, making the connection of a fabric with the production site a relatively easy task. In the absence of this, however, both an appropriate knowledge of the geology of possible source sites is needed, as well as an understanding of what changes will have occurred to the raw clay in its processing to become a tile, with the potential for material to have been added or removed, and a raft of possible changes that might occur during firing (*cf.* Chapter 4.2.1.). Published geological records are rarely, if ever, produced in a format that allows easy comparison with archaeological characterisation of ceramics, and thus might not be entirely suitable. Geological papers describing bedrock clays often focus on features such as fossil types and preservation, or material (geotechnical) properties of the clay, subjects of limited use to the archaeological analyst.[265] Systems of environmental sampling stand as the best method for creating a geological raw-material base line with which to compare the analyses of tile fabrics. However, this involves significant time and financial investment, and the task of identifying clays suitable and available to the Roman craftsmen, and therefore worthy of sampling, is not easy.

3. The final analysis method, the study of form, has perhaps seen less work than other methods. In comparison to the wide array of forms seen in pottery, Roman CBM normally falls into a relatively small set of standard shapes.[266] Thus brick or tile form seems to be largely undiagnostic beyond denoting a particular broad type, representing an idea of function (e.g. *tegulae* or *bessales*). Consideration of specialist products such as flue tiles

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[265] E.g. Parry (1972); Allison (1988); Anderson *et al.* (1994).
[266] Brodribb (1987) 3.

or chimneys offers the potential for interesting discussion of particular expertise in workshops.[267] One characteristic of form that has been noted in studies of Romano-British tile, potentially reflecting chronological change, is size: broad datasets suggest an overall gradual decrease in *tegula* size with time.[268] As mentioned earlier, a second form factor, that of lower cutaway type, has recently been re-analysed for its potential as a diagnostic reflection of time.[269] The theory behind this method is that the shape of the lower cutaways goes through a chronological progression, and through the analysis of datable *tegulae* with good phase information, broad date ranges can be assigned to the different cutaway shapes. This method has yet to be extensively tested by other archaeologists, with the only papers making systematic use of this technique being Warry's own.[270] Mills' recent survey does draw the basic premise of the technique into question by bringing in evidence from outside of Britain.[271] Beyond these criticisms, other problems of this methodology include a need to recover *tegulae* with intact cutaways: whilst this is something more commonly occurring than legible tile stamps, at least on British excavations, such fragments are certainly not going to make up the majority of most assemblages.

Summing up the total weight of work on Roman CBM, and looking in particular at work on material from Britain, whilst it appeared as a relatively fashionable topic in the 1970s and 1980s, it has certainly dropped from popularity since then, possibly showing a slight resurgence in the last 10 years or so. The conference held in Leicester in 1979, the proceedings of which were rapidly published in a volume edited by McWhirr, was a landmark, and contains some of the best work written on Roman tile and brick in

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[267] See e.g. Brodribb, Cleere *et al.* (1988).
[268] Warry (2006) 38.
[269] Warry (2006).
[270] Warry (2010), (2012).
[271] Mills (2013a) 440-446.

Britain.[272] Sadly however it is now out of date, with papers such as the editor's catalogue of known Roman tile kilns in Britain in need of updating.[273] Mills' 2013 paper stands out as a singularly important recent publication, its brevity the major downside; Mills' electronic map of known Roman tile kilns, based on data from the Archaeological Data Service, is a useful tool, and will be analysed in further detail later in this thesis (Chapter 5.4.2).[274] With the advent of new scientific and theoretical methods, a resurgence in the study of CBM with the application of novel, or at least modern techniques, is surely overdue. Work to date has shown that Romano-British CBM is not always just made locally, but on occasion travelled significant distances from kiln to building site.[275] Given the vast amount of successful work that has been carried out in pottery studies, making use of fabric analysis, surely similar success will be found if fabric analyses of CBM are regularly carried out to a high standard: on a regional level, particular fabrics will become better known and better characterised, and we will start to build up a more illuminating picture of the production and distribution of CBM. Recent papers, including several focussing on fabric analysis through chemical means, are welcome, but for the moment they are too few.[276]

3.1.4. Stone Building Materials

In contrast to the study of Roman ceramic building materials, in terms of total quantity, Roman building stone has received a far greater degree of attention, although being a natural material the avenues for insight are slightly more limited than with CBM: morphological studies rarely offer significant data (excepting some very interesting work that has been undertaken on stone-working techniques and the marks left on the material), and so petrological analysis for identification and provenancing of materials

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[272] McWhirr (1979a).

[273] McWhirr (1979b).

[274] Mills (2013a); URL = http://www.archaeologicalceramics.com/tile-kilns.html (access 16/10/14).

[275] E.g. Darvill (1979); Darvill and McWhirr (1984); Betts and Foot (1994); Mills (2013a).

[276] E.g. Finlay *et al.* (2012).

stands as the key research methodology, along with research into the associated economic and logistical questions surrounding extraction and processing.[277]

However, as Russell states, "research in this field remains irregularly spread and often highly targeted."[278] In particular, a very large proportion of the literature on stone use in the Roman world has focused on the topic of "marbles." The term has been used imprecisely in academia, the generally accepted meaning, as defined by Ward-Perkins being similar to the way in which Romans used the term *marmor,* referring to any "fine, hard stone that could be used for sculpture or high-quality architecture;"[279] others use it to refer to any stone which would take a high polish;[280] another term sometimes used is "decorative stone."

All of these names are imprecise and subjective. The distinction between, for example, a fine hard limestone capable of taking a high polish, and therefore labelled a "marble," and a limestone which is slightly less hard, fine or capable of being polished, and therefore not termed a "marble," demonstrates the arbitrary nature of the appellation, lying on a scale of continuous variation, and subordinate to subjectivity. Scholars have inadvertently been subscribing to a dichotomy of "decorative" stones versus other, presumably "non-decorative" stones, and this has had a resultant impact on the coverage of academic work. The distinction, flawed in the first place, has perhaps led to a lack of investigation of more nuanced classifications of building stones.

"Marble" was undoubtedly important in antiquity, the material of choice, where available, for statuary, sarcophagi, inscriptions, and the decoration of the grandest buildings, and thus it has been studied for decades.[281] However, the degree to which marbles have been

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[277] Wootton *et al.* (2013a).
[278] Russell (2013a) 3.
[279] Ward-Perkins *et al.* (1992) 13.
[280] Russell (2013a) 10.
[281] E.g. Ward-Perkins (1951), (1963), (1972), (1975), (1980); Gnoli (1971); Pensabene (1972), (1978), (1982), (1992), (1993), (1995), (2001); Fant (1985), (1988), (1989), (1992), (1993), (2001).

studied is surely not proportionate to their role in the wider Roman stone trade. As Russell remarks, marble quarrying, trade, and use "has become a leitmotif for imperial excess in modern scholarship, as it is in the works of ancient writers."[282] The majority (in terms of volume or tonnage) of the Roman stone trade must have been in local and regional scale economies, moving far less prestigious stones far smaller distances.[283] These smaller-scale economies have received considerably lower levels of academic interest than the grand imperial "marbles," despite the fact that they must represent one of the most important trades in the whole of the Roman world: the volumes of material required for a building project, the massive nature of stone, and the socially motivated desire to utilise non-local stones, seemingly across a wide spectrum of social levels (subjects to be returned to in Chapter 7.4), must have led to highly significant expenditure and employment in the stone trade.

The above-mentioned Association for the Study of Marble and Other Stones in Antiquity, ASMOSIA, was set up in 1988 with the intent to direct at least some focus onto those "other stones."[284] The nine edited volumes produced by the association cover a broad array of topics within stone studies, including quarries and quarry workers, stone dressing, scientific techniques for the provenancing of stones, and the varied uses of stone in antiquity. However, a survey of paper titles demonstrates that the intention to look beyond marble seems to have been unsuccessful to date. I have categorised the papers from the first seven volumes of the series by title keywords, the results of which are displayed in Table 3.1. The category titles are fairly self-explanatory, the first column including any article whose title refers to marble, marble quarries, marble statuary or architectural elements (e.g. columns or metopes), or those other stones regularly included in Ward-

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[282] Russell (2013a) 4.
[283] Russell (2013a) 5.
[284] URL = http://www.asmosia.org/history.html (accessed 20/5/14).

Perkins' broader categorisation of "marbles," such as porphyry, breccias, the fine Egyptian granites, and stones used to make smaller decorative artefacts such as soapstone or alabaster. The "Other stones" category includes those articles which make reference to stones other than those included in the first category, these commonly appearing in the context of building materials. The "Other" category includes article titles concerning subjects such as analytical techniques, quarry labour, and infrastructure, whose titles do not specifically refer to any particular stone type. The total number of articles across the seven volumes is 342.

Volume	**"Marble" and "decorative stones"**	**Other stones**	**Other**
I	42	0	7
II	25	2	7
III	31	1	8
IV	43	4	1
V	34	4	9
VI	53	9	5
VII	45	6	6
Total	273	26	43
%	79.8	7.6	12.6

Table 3. 1: Paper titles from ASMOSIA Volumes 1 to 7, categorised by stone type.

As can be seen, papers about "marbles" and "decorative stones" dominate the ASMOSIA volumes, with just under 80% of paper titles referencing them, and many papers in the "Others" column also in fact focusing on these stones. Volume VI has the highest number of papers addressing non-marble stones, and throughout the seven volumes one might identify a slight upward trend in interest in non-marble stones, but it is abundantly clear that the decorative stones, associated with the activities of the elite in the Roman world, dominate.

Exceptions to this pattern do exist however; successful work has been undertaken into the use and trade of "non-marbles," although unfortunately studies of building materials are still something of a minority. Across Europe analyses carried out with the aim of provenancing Roman mill stones, tomb stones, and stones used in "monuments" particularly stand out, especially in Germany.[285] In Rome, Jackson has explored the use and selection of volcanic rocks from local sources.[286] The situation in France is positive, with quarrying, particularly around the major *coloniae*, well studied. Nîmes, Autun, Lyon, and Paris have been the subject of such studies, showing how a large and immediate demand for stone was met with local, relatively small-scale extraction at multiple sites in the vicinity of the towns: presumably this is a pattern that might be seen across the Empire, if it was looked for.[287] At Lyon the granite and schist quarries, exploited in the early 1st century AD, later had competition from new limestone quarries further up the Rhône, providing freestones better suited to fine working: these included the quarries at Franclens, Fay, and Villebois on the Rhône, and Tournus on the Saône, demonstrating the importance in Gaul of the rivers for widening the areas of resource capture of towns.[288] Braemer has carried out research on localised patterns of stone use in France, although his work often focuses on marble and other "matériaux nobles."[289] Moxness' MPhil thesis on the subject of quarrying and stone supply to Nîmes demonstrates the powerful conclusions that can be drawn when quarries can be securely identified, and the startling quantities of material and labour needed in major civic projects.[290]

Russell's excellent recent book, *The Economics of the Roman Stone Trade*, serves as a summary of much of the work on Roman stone across the Empire, and covers a broad range of novel questions on the subject; the materials he considers are not just used in

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[285] E.g. Röder (1960); Noelke (1977); Bauchhenß (1978); (1979); Horn (1981); Schleiermacher (1984); Stribrny (1987); Williams-Thorpe (1988a); (1988b); Volterra and Hancock (1994); Stuart and Bogaers (2001); Maritan *et al.* (2003); Savay-Guerraz (2006); Gluhak and Hofmeister (2008).
[286] Jackson *et al.* (2005), (2011); Jackson and Marra (2006).
[287] Audin (1965) 233; Audin and Burnand (1975) 171.
[288] Bedon (1984) 27-30.
[289] Braemer (1971), (1982), (2004).
[290] Moxness (2010).

construction, but in statuary, sarcophagi, and other art forms.[291] Marble again dominates the work, but other stones are given space. The above-mentioned fourth volume of the *Arqueología de la Construcción* conference publications concerns quarry evidence, and includes a large number of studies of "non-marble" across the Empire; a very important recent contribution to the subject.[292]

Turning now to Britain, a literature survey here certainly demonstrates more of an emphasis on non-marble stones, although this is in large part due to the scarcity of marbles in this region, rather than a conscious effort of its scholars to study "less prestigious" materials. Perhaps as a result of this lack of a "marble myopia," very interesting work has been conducted. The work of J.H. Williams in the south of England in the 1970s is excellent, although not particularly well known: geological studies of stone-types used in Roman construction are used to explore the exploitation of available building materials, to elucidate trading patterns, and investigate how available building materials might influence architectural styles.[293] J.R.L. Allen and his various collaborators have achieved a great deal exploring stone use at various sites, and in particular have investigated the movement of stone, the reasons for choosing particular materials, and their subsequent spoliation and reuse.[294] Pearson's short work on stone and quarrying in Britain is useful.[295] Hayward's volume on the study of a sample of limestone gravestones and monumental architecture fragments stands out as covering exciting new ground.[296] It provides a valuable discussion of the quarrying, trade, and use of freestones excavated at Roman sites in the south of England. The bulk of the work focuses on the archaeometric characterisation of the Middle Jurassic limestones that outcrop in southern England, and

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[291] Russell (2013a).
[292] Camporeale *et al.* (2014).
[293] Williams (1971a); (1971b).
[294] Allen (2010); Allen and Fulford (1999); Allen, Fulford and Pearson (2001); Allen, Rose and Fulford (2003).
[295] Pearson (2006).
[296] Hayward (2009).

importantly also shows the transport of a particular limestone (Calcaires à Polypiers) from northern France into Britain as well.[297] The work of all of these authors creates a useful paradigm to follow, and Hayward's "integrated petrographic methodology" provides a useful database of the results of multi-analytical approaches applied to southern British limestones with which to compare stone samples from this study.[298]

Hayward's demonstration of the transport of "non-marbles" significant distances shows the problem with the received dichotomy between "marbles" and "non-marbles." It must be recognised that in social and geographical spheres where the most prestigious stones were not available for use, there will still have been a hierarchy of materials: just because the very top-class materials were economically unobtainable, plainly this did not mean all those below were considered and used equally. Many of the same social and economic structures that influenced the choice of the most prestigious marbles in Rome can be applied to relatively poor quality stone in Britain, which stimulated significant trade.[299] Surely this hierarchy of materials will continue right down to the lowest social classes involved in construction, and the lowest qualities of building materials as a whole. This material economy will thus have had an impact upon a vast proportion of the population of the Roman Empire.

Summing up work on Roman building stone, we see a somewhat more positive picture than the study of ceramic building materials, but certainly a subject which needs to broaden its focus. The area of research that has received most attention recently is that of provenance studies, these being crucial to the reconstruction and analysis of ancient commercial connections and trade routes. Economic discussions have been frequent, with subjects such as material and quarrying costs, transport costs, and labour costs now

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[297] Hayward (2009) 83-93.

[298] Hayward (2009) 22 and Appendices 3, 4 and 6.

[299] Hayward (2009) 106-107.

regularly appearing in scholarship.[300] These are important areas of questioning, and now need applying to lower quality building stones, which have just as much to tell us about Roman society as the finest marbles in the Empire.

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[300] The contents of the ASMOSIA volumes furnish many examples of all of the above. *Cf.* Herz and Waelkens (1988); Waelkens, Herz *et al.* (1992); Maniatis, Herz *et al.* (1995); Schvoerer (1999); Herrmann, Herz *et al.* (2002); Lazzarini (2002); Maniatis (2009).

3.2. What Can We Learn From Roman Building Materials?

In this section we will explore what it is actually possible to learn from the study of Roman building materials. Given the low level of intensity of work in this subject area there are still significant flaws and hurdles to be surmounted in the study of the material, with site reports and specialist studies often either failing to utilise the full potential of the material or pursuing a flawed line of reasoning or methodology. Thus we begin here by going back to the basics and reflecting on the intrinsic characteristics of these materials; through these we will explore the insights we can possibly gain into the material, and the broader environments (physical, economic, and social) within which they were made and used. This analysis of the viable lines of questioning will then be focused towards the particular circumstances of the Dorchester assemblage to consider what questions we can ask of it, taking into account its character, burial context, chronology, and a detailed survey of the local geology.

Whilst one of the ultimate aims of this thesis is the synthetic analysis of multiple building materials, at this initial stage surveying the innate characteristics of each, ceramic and stone building materials will be treated separately. This is because they are incomparable in several senses. Of the various material properties of these two materials that we can measure, all of those of archaeological CBM were in some way created or influenced by the choices and actions of humans. For stone, being a natural material, this is not the case, with only some aspects of its character, e.g. shape, determined by human hands. Thus CBM and stone will initially be reviewed separately here. However, it will be seen that despite their differences, the two materials can inform us about fairly congruent sets of questions: we gain overlapping fields of view onto Roman production, distribution, and use of these artefacts, and into the materiality of building components. Thus, following the separate review of the two materials’ chaînes opératoires characteristics, we will discuss the questions that can be asked of their creation, function, and materiality, with ceramic and stone treated together as a synthesised artefact group: building materials.

3.2.1. Ceramic Building Materials

As stated above, being of man-made origin, many, if not all, facets of the character of individual pieces of ceramic building material were purposefully or accidentally influenced by the actions of the makers and users of the material. With careful analysis and consideration some of those actions and choices might be retrospectively discernible through their impact on the material. It is one of the key goals of this thesis to attempt to interpret these. It is acknowledged here that this exercise is, by its nature, a cyclical activity: we cannot hope to read meaning from the various anthropogenic characteristics of a piece of Roman CBM without first knowing something about how those characteristics might have been created or influenced, yet it is these influences which we are attempting to clarify through the analysis of the characteristics. It is impossible, and would be futile, to learn anything from an utterly uninformed starting position, and the iterative nature of the task is fully recognised.

Thus in order to attempt to escape any bias or pre-formed conclusions, at this stage I present a very brief examination the main steps in CBM production and use – a basic chaîne opératoire. For this theoretical exercise of simply considering the range of questions that can be asked of this material, this simple approach is sufficient to demonstrate the range of metaphorical 'fingerprints' left in the material from its creation, that we as archaeologists can attempt to interpret. When I come to interrogating and discussing the primary archaeological material in the subsequent chapter, the full circumstances of the chaînes opératoires will be challenged in detail, and reconstructed as closely as possible.

3.2.1.1. A Simplified Chaîne Opératoire for CBM

Ceramic building materials were used in several ways in Roman construction, from bricks used in a structural capacity (combined with mortar), to roofing material, through to components of heating systems.[301] As discussed in Chapter 2, in Roman Britain brick-built structures were comparatively rare. The majority of CBM found on most Romano-British archaeological sites tends to be roof tile, principally *tegulae* and *imbrices*. The box flue tiles of cavity wall heating or insulation systems are also frequently observed. On account of their dominance, here we will primarily concern ourselves with roofing tiles.

The basic chaîne opératoire for CBM can be divided into five main steps: the selection and extraction of raw materials, their processing, their firing, the building material's use (and possible reuse), and finally its deposition (Fig. 3.1).

Figure 3. 1: A simple chaîne opératoire for CBM production.

The selection and extraction of raw materials for CBM production centres on clay. This material will be discussed in more detail below, but here we should briefly note that there is great variability, in terms of mineralogy and chemistry, between different clays, and that not all would be suitable for ceramic production. The composition of the clay will have had a significant and direct impact on how workable it was, how the material fired, and the properties of the finished product. As such, the selection of a clay would be a very important part of the production process.

Following extraction a clay might be subjected to types of alteration in order to change, and presumably improve, its properties. This could include the 'souring' of the material

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[301] Brodribb (1987).

through exposing it to natural weathering for a period of time, with biological, chemical, and physical processes affecting the clay.[302] The clay may also have been altered through the addition of other material, including mixing different clays together or adding 'temper' such as sand, shell, organic matter, or grog (crushed already-fired ceramic).[303] Alternatively matter might have been removed from the clay, i.e. it was "purified," through the removal of large particles, pebbles etc. by hand, or through levigation, whereby clay was disaggregated in water and a certain fraction or fractions of particles were removed.[304]

Next in the production procedure would be the forming of the clay into the desired shape, drying it, and then firing it. *Tegulae* and *imbrices* may have been manufactured in a range of ways, requiring the use of different mould types or formers and various tools and techniques.[305] Following forming, drying the material was crucial, as any significant levels of moisture present in the clay during firing could lead to the piece exploding. Firing might have taken place in a number of ways, from single-use 'clamp-kilns,' to large, well-built reusable kilns, with variation detectable in firing atmospheres, temperatures, and times.[306]

Finally we have to turn to the post-production processes to which the material was subjected. These would have included its movement from the kiln site to building site, its inclusion in a building, and eventually its deposition in the archaeological record. Unless produced on the building site, depending on the economic structures in place, the movement step may have involved some form of marketing and trade.

The CBM would then have been used in the building, and through time may have been re-purposed in subsequent roles through spoliation and recycling: being a highly resistant material, and *tegulae* being a convenient rectilinear shape, roof tile was often subsequently

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[302] Hamer and Hamer (2004) 345.

[303] Orton, Tyers and Vince (1993) 71; Quinn (2013).

[304] *Cf.* Peacock (1982) 54; Swan (1984) 44; Orton, Tyers and Vince (1993) 117; Quinn (2013).

[305] Warry (2006) 28-37.

[306] McWhirr (1979b) 97-101.

used in walling, a flat top surface created simply by removing the flanges.[307] CBM would eventually have ended up in the archaeological record through deposition as waste, either deliberately discarded or from the dereliction and decay of the structures in which it was used. It is then uncovered during archaeological excavation.

3.2.1.2. CBM's Differing Fingerprints

Each of these steps will have altered the character of the CBM in some way, leaving behind 'fingerprints.' Some steps or actions might be fairly apparent with a brief visual inspection, such as incised marks left on the surface of the wet clay; others might require more detailed analyses, such as the identification of temper by thin section microscopy. Some 'fingerprints' will be the result of multiple actions of the producer, and thus it might be somewhat more difficult to identify each individual action from the composite result they have on the tile: for example, the choice of clay, its processing, and its firing will all come together to give the final body colour and chemistry. Untangling the precise conditions and input of each action is difficult.

This complex, multi-faceted nature of the character of fired-clay means that studying a single piece of CBM in isolation is not especially fruitful; to have the best chance of understanding the variables an analysis of multiple different pieces is necessary. In this situation our aim is to identify *difference* in the character between pieces, as this has the greatest potential for helping us to identify and understand differences in the chaînes opératoires of different pieces, and thus to gain a more detailed impression of the production and use of ceramic building material in the Roman period.

The range of differences seen in ceramic building material can be categorised into three main groups: form, markings, and material or "fabric." The form of the tile includes variables such as its dimensions, shape, and tile type. Markings on the tile might include

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[307] *Cf.* Parsons and Sutherland (2013).

intentional lines, smears, cuts, or stamps made into the unfired clay with the fingers, a knife, or a stamp. And the "fabric" of a tile is the sum of the physical characteristics of the fired clay, including its appearance, structure, and composition; macroscopic features such as colour, texture, and hardness form a part of this, along with microtextural, mineralogical, and chemical characteristics.[308]

Within each group are a number of specific sources of difference, which are set out below in Table 1. Not every tile will exhibit every single example (particularly some of the 'markings' category), but some sources of difference are integral to every piece of CBM (such as colour, inclusions, or chemical composition), and thus can be analysed in every single case. As mentioned above, each difference might enlighten us on a number of aspects of the life-cycle of CBM; these aspects can themselves be broken down into four main areas of questioning we might use to understand the chaînes opératoires of Roman CBM; these are briefly set out in the third column, and are discussed more below and in Table 3.2.

Broadly, differences in form, such as tile type, shape, and marks from production, might elucidate information on the forming and production processes, perhaps the logistics necessary for moving such material, and the different functions and uses it performed. Differences between artefacts on account of markings, such as stamps or tool marks, might again enlighten us towards production processes and organisation, the identity of the producer or manufactory owner, the origin of the material, the organisation of its distribution, or the broad use of the material. Differences in the material character or "fabric" of the artefact might point towards its origin, opening up questions about distribution, the effectiveness of an object's functionality, being better or worse quality, and this can be connected to social prestige.

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[308] Orton, Tyers and Vince (1993) 132.

Sources of *difference* in CBM		Can tell us about:
Form	• Shape, dimensions, weight • Tile 'type' - tegula, imbrex, box flue etc. • Tile 'cutaway' and ‘flange’ shape • Finish • Manufacturing/tool marks • Affixing means (e.g. peg holes, mortar) • Breaks, abrasion	• Production process, technology, tools and equipment, associated industries. • Distribution pattern, costs, reasons. • Practical function, why used, functional properties, aesthetic properties, social function. • Chronology, deposition, post-depositional environment.
Markings	• Stamps • 'Signatures' • 'Tally marks' • Decoration - moulded, incised, combed, carved etc. • Graffiti • Accidental marks (e.g. animal footprints)	• Production process, organisation of production, maker, owner. • Origin, distribution organisation, distribution distance, means, and routes, individuals involved, distribution reasons. • Practical function, why used, social functions, aesthetic properties. • Chronology.
Material, 'fabric'	• Colour • Texture • Density • Hardness • Porosity • Inclusions • Chemical composition	• Production process, organisation of production, technology, production costs, associated industries. • Origin, distribution organisation, distribution distance, distribution reasons. • Functions, why was it used, functional properties, social function, aesthetic value. • Chronology, post-depositional activity.

Table 3. 2: Sources of difference in CBM and the question areas for which they provide insight.

3.2.2. Stone Building Materials

As indicated at the start of this chapter, the analysis of stone building materials presents a very different task to archaeologists from the analysis of CBM. Being entirely created through man-made choices, from shape to material, fired clay objects offer a great deal of clues towards Roman crafting, economy, and society, albeit that this insight is obscured by the complex puzzle that CBM’s multi-faceted nature presents. Stone building materials on the other hand have a rather shorter chaîne opératoire, individual pieces often only needing quarrying, and possibly shaping, before being included in a building project. With fewer functional steps comes less opportunity for anthropogenic *difference* to be created, and thus we have fewer variables to analyse. Nevertheless, those that can be identified still provide insight onto the organisation of Roman building material production and construction.

3.2.2.1. A Simplified Chaîne Opératoire for Stone Building Materials

Building stone performed two main functions in Roman construction in Britain, being used either in walling, or as roofing material, and these different functions would have necessitated different material properties. The first step in the production of these materials would be the selection of a raw material suitable for the task at hand: for wall stone this might mean choosing a stone apt for making fairly regular blocks usable in mortared rubble construction (with little or no further working needed), and with good strength under compression. For roofing this would mean selecting a stone that could easily be split into relatively thin but strong 'tilestones.' In both cases resistance to weathering would be desirable, as would an ease of working, provided by a regular mineral structure with few serious anomalies that might create lines of weakness.

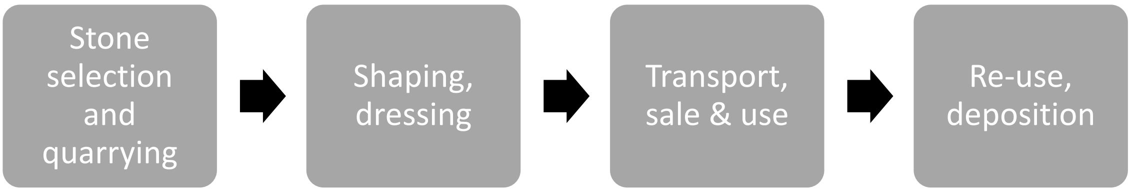

Figure 3. 2: A simple chaîne opératoire for building stone production.

Stone would most commonly have been exploited in locations where it outcropped, such as in hill sides or river valleys (Chapter 5); having a face to work into horizontally is easier than attempting to dig a quarry vertically downwards.[309] Following the selection of a usable stone outcrop, this would then be quarried and gathered; in some locations natural weathering processes alone might have eroded suitable stone from an outcrop face;

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[309] Wootton, Russell and Rockwell (2013b) 3.

alternatively extraction would have involved a labour force and appropriate tools, including most commonly shovels and mattocks for the clearing of topsoil, and pick-axes, hammers, chisels, and wedges for the breaking of the stone.[310]

Following extraction of suitable blocks these might then be further worked to improve their shape; if being used in simple rubble-construction this would be unnecessary, but for special blocks such as ashlar, lintels, quoins, voussoirs, or decorated carved stones, more work would be needed, undertaken by a skilled mason using a hammer, punch, and chisels.[311] This might be conducted at the extraction site if the forms and dimensions were standard or already known; alternatively the stone might be transported unworked to a mason's yard, or directly to the construction site, and would be shaped by a mason there.[312]

This does not represent the end of stone's chaîne opératoire, as, like CBM, stone was regularly recycled when the original building decayed or was pulled down.[313] Stone gathered in this way would have been far cheaper than quarrying new material, as many of the blocks might be perfectly usable, requiring no further shaping, and in cases of continuity of settlement sites, they might already have been close to the new building site, cutting out significant quarrying and transport costs. Stone might be recycled in this way for long periods of time, before ending up in the archaeological record, and discovered through excavation.

3.2.2.2. Stone's Differing Fingerprints

As already mentioned, stone building material generally exhibits fewer 'fingerprints' than CBM, with the actions and choices available to the Roman masons and construction workers more limited. Nevertheless there are still useful aspects to be analysed, and again

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[310] Adam (1994) 31; Wootton, Russell and Rockwell (2013b) 3.

[311] Wootton, Russell and Rockwell (2013a).

[312] Wootton, Russell and Rockwell (2013b) 5.

[313] Eaton (2000).

an approach which surveys an entire assemblage in order to identify *difference* between individual pieces is the most powerful.

Compared to the three categories of ‘fingerprints’ identified for CBM, we might group the means by which we can characterise building stone into two groups, ‘Form,’ and ‘Material.’ Form includes aspects such as the shape of the piece (a pentagonal roof tile, an unshaped piece of rubble for walling, or a squared quoin), the way its faces and edges were worked and indicators of the tools and techniques employed, any signs of the ways it was fixed in place (adhering mortar, or a clamp or peg hole), and signs of abrasion or wear from use. The characterisation of the material or “fabric” follows many of the same lines as that of ceramic building material, with aspects such as stone type, colour, texture, fossils present, and mineralogy all analysable.

These various ‘fingerprints’ are set out in Table 3.3, along with the question areas for which they can inform our understanding.

Sources of *difference* in stone building materials		**Can tell us about:**
Form	• **Shape, dimensions, weight** • **Edge/face forming** • **Decoration** • **Manufacturing/tool marks** • **Affixing means (e.g. peg holes, mortar)** • **Breaks, wear, abrasion**	• **Production process, technology, tools, organisation of production.** • **Distribution, organisation, distribution costs, distribution reasons.** • **Practical function, why used, functional properties, aesthetic properties, social function.** • **Chronology, recycling, deposition, post-depositional environment.**
Material, 'fabric'	• **Stone type** • **Colour** • **Texture** • **Density** • **Hardness, strength** • **Porosity** • **Mineralogy, fossils** • **Chemical composition** • **Workability**	• **Origin, distribution organisation, distribution distance, cost, means, route, distribution reasons.** • **Functions, why was it used, functional properties, social function, aesthetic value.** • **Post-depositional environment.**

Table 3. 3: Sources of difference in stone building materials and the question areas for which they provide insight.

3.2.3. What Can Building Materials Tell Us?

Based on the above general schemas for the production of ceramic and stone building material in Roman Britain, and the aspects of these materials which we can characterise, we can now explore the range of questions we can ask of these artefacts. Despite the different 'fingerprints' detectable in the two types of materials, as can be seen in Tables 3.2 and 3.3 above there is still a significant overlap in the subjects into which we gain insight.

Many of these subjects are interlinked, but might broadly be grouped into four categories. The first category includes questions about choices made in the production of the material: the raw material extraction, the production processes, the organisation of production, technologies, tools, and equipment used, people involved, manpower required, costs involved, and linked crafts or industries. Secondly, questions about distribution can be asked, through enquiries into the origin of artefacts, the organisation of distribution, the transport distances, the means and logistics of transport, routes used, and costs and agents involved. The function and use of building materials is the third area of questioning, as we look at their functional properties, the ways they were used, and building materials' materiality, social significance, and aesthetic value. Finally we might question building materials for information on site formation, chronology, recycling, and post-depositional processes. These four question areas are set out in Table 3.4.

Area of questioning	Specific questions
Production	• **What was the chaîne opératoire, the detail of the process of production/extraction?** • **How was the production/extraction organised?** • **What technologies were used?** • **Who were the people involved?** • **What costs might there have been?** • **Were there associated industries or crafts?**
Distribution	• **Where was the material made/extracted; where did it end up?** • **How was this movement organised?** • **How far did it move?**

	• **By what means did it move?** • **By what routes did it move?** • **What costs might there have been?** • **Who were the people involved?** • **Why did it move?**
Function	• **For what was the material intended to be used?** • **How was the material actually used?** • **Why was it used?** • **What functional properties did it have?** • **What social and cultural functions did it perform?** • **Did the material have aesthetic value?**
Site processes	• **What does the material tell us about the creation of archaeological deposits?** • **What does the material tell us about the chronology of sites?** • **Was the material recycled?** • **What does the material tell us about post-depositional activity?**

Table 3. 4: Questions which might be asked of Roman building materials.

3.2.4. Archaeology and Geology

Both material groups considered above have their origins in geological deposits. Understanding the regional geology is therefore a critical part of understanding archaeological building materials, in particular in answering questions of the origin, processing or alteration, and distribution of the material. In this section some consideration of the difficulties of marrying geological and archaeological studies will be given, before looking in more detail at the geology of the study region, with a more in-depth catalogue of geological units presented in Catalogue 1.

3.2.4.1. Missing Geological Detail

The scientific characterisation of British geology is most commonly based upon the analysis of lithology, mineralogy, and palaeontology, allowing for the distinction between deposits considered different geological 'units.'[314] Distinct units are classified into *Formations*, themselves part of larger *Groups*, and within *Formations* exist lesser units called *Members.* The Middle Jurassic White Limestone Formation, for example, is a part of the Great Oolite Group, and can itself be divided into three Members: the lower Shipton Member, the middle Ardley Member, and the upper Bladon Member.[315] Britain's geology has been relatively intensively studied, and the excellent maps with accompanying *Memoirs* produced by the British Geological Survey are a powerful resource for assisting in this research. However, the task of attempting to match archaeological stone with geological deposits, using the published literature, is very difficult. This is down to a number of reasons.

Much of the mapping and analysis of Britain's geology was begun more than a century ago. There is an ongoing programme of updates and revisions to the various mapping areas

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[314] Press *et al.* (2004).

[315] Sumbler (1984).

into which the country is divided, in line with new discoveries and data, but the scale of the task means that some regions have not been reviewed as recently as others: the most up-to-date geological map of north west Oxfordshire for example was published in 1982.[316] Further, this map is heavily based on the original one-inch geological survey of the region carried out between 1856 and 1863, reviewed in 1908, 1938, and the 1982 edition is based on survey work undertaken between 1973 and 1975. Since that time significant developments have been made in our understanding of the region, some formations having been renamed or even entirely redefined since then, and many subdivisions and correlations have been shown to be invalid.[317] The most recent accompanying M*emoir* for the map was published in 1946.[318] Plenty of academic work has been undertaken on the region in the last few decades, predominantly through new borehole core analyses (as opposed to earlier surveys which were largely reliant on exposures created in quarries or cuttings for road or rail infrastructure). Thus a great deal of care needs to be taken when reviewing the subject, in order to ensure that the literature consulted is the most up-to-date.

It might be hoped that an archaeological material could fairly easily be tied back to the formation from which it was sourced, or even better could be attributed to a particular member. Unfortunately however this is rarely possible. Many deposits appear very similar, on account of the fact that the same depositional conditions have recurred through time. Frequently deposits are only described in academic literature according to a broad lithological characterisation (e.g. the Ardley Member of the White Limestone Formation is described as “white to buff micritic and sparry limestones with varying proportions of shell debris and peloids”), along with a description of fossil species present in the stone.[319]

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[316] Geological Survey of England and Wales (1982).
[317] E.g. Sumbler (1984); Hey (1986); Boneham and Wyatt (1993).
[318] Richardson (1946).
[319] Sumbler (1984) 55.

This is problematic in a number of ways. Firstly there will be multiple deposits in the Jurassic limestones of the Cotswolds that could fit this broad description, and indeed there could even be significant overlap in fossils present through different deposits: not even this extra level of characterisation would necessarily be diagnostic. Thus even when well described, an archaeological stone could feasibly be connected to multiple different source formations. Secondly it is now widely understood that there is a very high level of both vertical and horizontal variation within deposits, be they formations, or even the higher order of classification of members: the categorisation system must not be understood to imply homogeneity. Figure 3.3 shows schematically the variation understood within the White Limestone Formation and its constituent members, demonstrating that we cannot consider even members as consistent, predictably occurring, and precisely definable.[320] This issue is perhaps even more acute with regards to clays: the Kimmeridge Clay Formation was initially divided into two parts, the Upper and the Lower, but has relatively recently been reanalysed and subsequently divided into 62 different recognised sub-units or 'facies,' ranging in character from limestones and dolostones to shales, marls, and mudstones.[321] It should be assumed that any geological formation might exhibit similar levels of complex depositional and lithological variation, if studied in as much detail.

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[320] Sumbler (1984).

[321] Gallois and Cox (1994); Gallois (2000); Morgans-Bell *et al.* (2001).

Figure 3. 3: A schematic cross-section of the White Limestone Formation and Forest Marble Formation. Length of section c. 45 km. (After Sumbler 1984 Fig. 2.)

A final issue lies in the fact that the same formations outcrop in different places. Indeed some large formations, such as the Kimmeridge Clay Formation, might be found outcropping over thousands of square kilometres (in this case, onshore from Dorset to North Yorkshire, and offshore into the northern North Sea) and might have been worked for use in a number of different locations. Thus attempting to reconstruct routeways and the economics of the distribution of a particular material becomes highly problematic, if an individual extraction site cannot be precisely identified.

Given the task at hand, geological literature raises a further problem. As archaeologists, pursuing the range of questions outlined above (Chapter 1.1 and Table 3.4), we are interested in aspects such as the mineralogical properties of clays that might be found in fired ceramics produced from them, or the qualitative characteristics of a stone that made it attractive for use in construction. The geological literature is naturally primarily concerned with other matters, such as the fossils found within formations, their hydrocarbon content, and geotechnical properties which might make them valuable to industry. As Gale *et al.* note on the subject of the Gault Clay (the bedrock on which Dorchester sits), "although the Gault Clay in southern England has been the subject of extensive macro- and micro-palaeontological research, and detailed biostratigraphy, the petrography and mineralogy remain very poorly known, a situation which obtains in many mudrock successions."[322] As a result there is significant work to be done to find and extract information from the geological literature which is of value to an archaeological study. And beyond even this, it must obviously be remembered that the way modern geologists or archaeologists consider these materials will be entirely different from the Roman conception of them: the ways Roman craftsmen may have approached the landscape to exploit its natural resources must be considered.

3.2.4.2. Difficulty Defining Clay

A second difficulty to consider concerns the use of the term 'clay.' This is a term that is used in different ways in different contexts, and can refer to diverse materials; to properly understand the term, both in regard to enquiring how Romans chose material for producing ceramics, and with regard to interacting with modern geological research, we need to be aware of the varied ways in which it can be defined. There are three main ways in which the term is used.

Firstly, in its most technical sense, the term is used to denote so-called 'clay minerals.' These are a collection of hydrous aluminium phyllosilicates, including the kaolin, smectite, illite, and chlorite groups of minerals.[323] These are relevant to the study of archaeological ceramics as a close analysis of the various clay minerals present in an artefact and their proportions can assist us in learning more about its production and the raw materials used. Modern geological literature often discusses clay minerals present in

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[322] Gale *et al.* (1996) 287.

[323] Hillier (2003).

deposits on account of the differing geotechnical properties they lend to the clay, but does not present the data in ways which could assist an archaeologist trying to identify a particular clay through archaeometry.[324] Nor does it assist in unpicking the ways different proportions of the various clay minerals affect the working, firing and final material properties of ceramic artefacts.

Secondly, 'clay' is a term used by soil scientists and sedimentologists to refer to the smallest particle size fraction of sediments; it sits at the bottom of a spectrum running from boulders, pebbles, gravel, sand, down to silt, and then down to clay. The horizons which divide these fractions are defined at different points by different academic disciplines: sedimentologists tend to use a particle size of less than 4 μm to define clay, whilst geologists and soil scientists often use a size of less than 2 μm.[325] On account of being a definition based on size, and not any chemical or mineralogical determination, a 'clay' in this sense can exhibit a very broad array of characters, and could be made up of any variety of minerals and rock fragments, as long as they have been made small-enough.

Under both of the above definitions, just because a particular sediment might be termed a clay does not necessarily make it a useful, usable material for the production of ceramics. As such a broader definition is required when considering what sediments might have been exploited by the Romans for producing CBM, regardless of whether they contain minerals other than clay minerals, or whether they have particles larger than 2 or 4 μm. Thus the term 'clay' is also used to describe any fine-grained sediment suitable for making ceramics, having the properties of being plastic, i.e. mouldable, when wet, and non-plastic upon drying or firing. Such material might, besides clay minerals, also contain certain proportions of rock fragments, fossils, metal oxides, silt, sand, and organic compounds.

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[324] E.g. Parry (1972).

[325] Guggenheim and Martin (1995) 255.

Clearly it is the latter definition which is most relevant for our thinking about Roman ceramics, but all are worth bearing in mind when bringing together geological literature with archaeological discussions.

3.2.4.3. The Geology of the Upper Thames Valley

With those caveats and difficulties borne in mind, the geology of the study region will now be considered. A full catalogue of geological units is presented in Catalogue 1, whilst a brief overview is presented here.

The Upper Thames Valley landscape is defined by outcrops of sedimentary Jurassic and Cretaceous age rocks, overlain by Quaternary deposits.[326] The bedrocks are generally tilted downwards to the south east, so that the oldest rocks outcrop in the north west of the county, the youngest in the south east. The outcrops run in roughly parallel, west to east bands of alternating hard and soft geologies. These formations were created both by the fluctuating environmental conditions present in the region c. 100 – 170 million years ago, and the changing inputs of material: parts of Oxfordshire were at various points covered by shallow tropical seas, deeper seas, rivers, deltas, marshes, mud flats, and lagoons.

Beginning in the north, the uplands of the Cotswolds are largely formed from oolitic limestones; coming south down their dip slope we reach the Oxford Clay, over which the Thames runs for the first part of its course; the ridge of the Corallian Limestone defines the southern edge of the Upper Thames Valley along the first part of its course, which itself dips down onto the Kimmeridge Clay of the Ock Valley and the Vale of the White Horse. A small outcrop of Portland limestones and the Lower Greensand divides this from the Gault Clay, on which Dorchester itself sits. Finally to the south the Upper Greensand

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[326] Richardson (1946); Arkell (1947); Cox and Sumbler (2002); Powell (2005).

outcrops before the steeply rising scarp slope of the chalks of the Chilterns and North Berkshire Downs (Fig. 3.4).

A number of these bedrock units might feasibly have provided clay for brick and tile making, including the extensive Oxford Clay Formation, Kimmeridge Clay Formation, and Gault Clay Formation, and also argillaceous layers and localised facies in the Charmouth Mudstone, the Kellaways Formation (grouped with the Oxford Clay in Fig. 3.4) and the West Walton and Ampthill Clay Formations (grouped with the Kimmeridge Clay in Fig. 3.4).

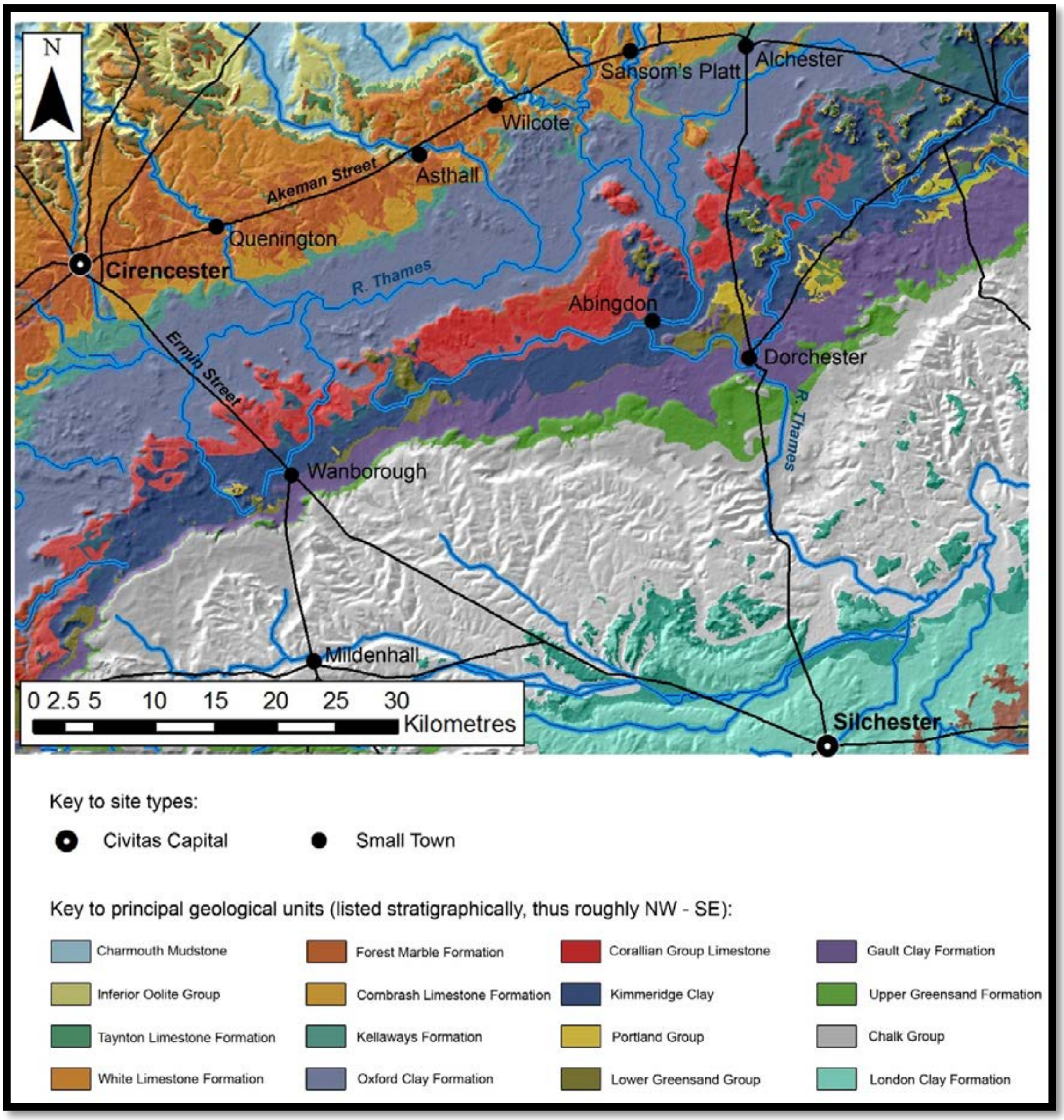

Figure 3. 4: Major geological bedrock units of the Upper Thames Valley and its environs. Geological Map Data BGS © NERC 2015. Roman road data © Historic England 2015.

Across parts of the landscape Quaternary age superficial deposits overlie the Jurassic and Cretaceous bedrocks. These were formed by glacial and fluvial processes acting on the landscape over the last two million years: glacial boulder clays, gravels, and till were deposited by the advance and retreat of ice from the north, and the major and minor valleys of the Thames and its tributaries, carved by rivers swollen with melt water, deposited the gravel terraces and fluvial sediments that cover much of the bedrock in the bases of the river valleys.

Not only did the glaciers carry material, but the inundation of meltwaters coming from their bases will have meant the rivers of the region, notably the Thames and Evenlode, were much larger than now, and so carried more material and held greater erosive power. Together these processes led to the creation of the Freeland Sand and Gravel Member (formerly known as the Northern Drift or Plateau Drift), which contains Triassic Age pebbles, and the Upper Thames Valley Formation, which is made up of the sand and gravel terrace deposits including the Hanborough Gravel, the Wolvercote Sand and Gravel, the Summertown-Radley Sand and Gravel, and the Northmoor Sand and Gravel.

The sand and gravels are of significant economic interest (primarily as aggregate in the building industry), but their exploitation does not warrant the same detail of geochemical study that has been applied to bedrocks. Clays form only a minor (and economically unimportant) part of the superficial deposits. As such, data on their composition are limited.

3.2.5. In What Ways Can We Therefore Question the Dorchester Assemblage?

In conclusion, based on these surveys, we can now consider how we can question the Dorchester assemblage. Of the three main categories of *sources of difference* between pieces of CBM (Form, Markings, and, Material), or the two *sources of difference* between pieces of building stone (Form and Material), it is the last category that is perhaps most promising for a focus of analysis. Given the high level of fragmentation of the assemblage and that complete dimensions, stamps, or other marks are absent, neither the Form nor Markings of the material provide promising routes to gaining a greater understanding of the Roman building trade. There are indeed significant difficulties inherent in trying to match a fired ceramic with a geological clay on account of the changes the firing process makes to the clay, because of the variation present in geological deposits, the lack of precise mineralogical and chemical reporting of these, and the difficulty of identifying

Roman clay extraction sites. Similarly it has been shown that stones can be just as hard to match with their sources.

However, this approach, of studying the material character of the artefacts, has the potential to be extremely powerful. This is a characteristic that is analysable in all pieces of material, no matter how fragmented they are. As Tables 3.1, 3.2 and 3.3 show, this is a category of analysis that also has the potential to offer insight onto the full range of question areas, with material character able to inform on aspects of production, distribution, use, and site processes.

Therefore the particular avenues of research, in line with the research aims set out above, will include:

- Trying to better understand from where the building material at Dorchester is coming;
- Trying to characterise the nature of material extraction and production;
- Exploring the means, routes, and nature of its distribution;
- Studying the ways in which it was used and the social and economic factors involved in its use.

4. Experimental Methodology and Results

"A primary requirement for the future is for an increasing proportion of ceramic studies to adopt the holistic approach… in which production, from the procurement and processing of the raw materials through to firing the pottery, is considered together with provenance and use." – Tite (2008) 228.

4.1. Methodology

There is a range of different approaches that have been taken for the analysis of ceramic and stone materials in archaeology, and all have their strengths and their weaknesses, times when they are most applicable and times when they yield little information of use. As has been discussed in Chapter 3, for archaeological building materials specifically, being only infrequently and un-systematically studied, there exists no rigid, well-tested framework for their analysis.

The development of the analytical methodology used in this research has been influenced both by an initial thorough consideration of the assemblage to be studied, its wider archaeological context, the methods available, and, through an iterative process, reflective refinement of the selected methods to ensure that appropriate data are collected, with satisfactory accuracy and precision.

This section will begin by setting out a summary of available analytical methods and their potential advantages and disadvantages for application in this research. Both approaches to ceramic building materials and stone building materials will be considered, as whilst there is some overlap in methodological approaches, there are also categorical differences in how these materials have been studied in the past. This summary will be followed by a detailed account of the methodology developed for use here, and then the results of the analysis, with a discussion of the key points and trends.

4.1.1 Methods Available for the Analysis of Building Material Fabrics

As has been discussed above, in many situations, and certainly in the case of the Dorchester material, the building material assemblage is highly incomplete.[327] In many environments Roman structures were heavily robbed for their still-useable materials, leaving the unusable fragmentary pieces behind. From this remaining assemblage the incidence rate of epigraphy is very low, and even incidence of complete dimensions or intact morphological features such as *tegula* cutaways is low. Cataloguing these features with a sample size large enough for drawing any significant conclusions from any particular site, in the absence of exceptional preservation, is very unlikely. As a result we must turn to the field of analytical methods, which are applicable to every sample: fabric analysis, in the case of ceramics, and lithology for stone. From this point forwards "fabric" will be used to refer to both ceramic and stone materials.

Fabric analysis involves the characterisation of the mineralogy, petrology/lithology, chemistry, and texture of the building material sample, with the potential to tell us about the nature and origin of the initial raw material and the processes to which it was subjected. Given the multi-faceted nature of a fabric there are a number of analytical techniques from which to choose. Hand-specimen, hand-lens and binocular microscopy inspections are integral initial steps in any study. The aims of these first steps include gaining a broad understanding of the variation across an entire assemblage, with hand-specimen examination allowing a general description of sample colour, macro-texture, and particles of sand-size or above.

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[327] Munro's work on the villa at San Giovanni di Ruoti gives an extremely low value of CBM recovery, just 120 kg out of a predicted 132,500 kg of roof tile used in the construction, a recovery rate of 0.01 %: Munro (forthcoming); Small and Buck (1994) 132-3 and Table 7.

This initial work is often, although not always, followed by thin section plane- and polarised-light microscopy: the inspection of the sample as a polished, 30 μm thick section mounted on a glass slide. This technique allows a much higher level of magnification for describing clay-body or "cement" character and inclusions or clasts, and the diagnostic capabilities of the microscope's analytical functions enables minerals to be identified. The methodology employed by Whitbread is the traditional standard approach for ceramic material, updated most recently by Quinn.[328] In many excavation reports, particularly those of commercial archaeological excavations, hand-specimen descriptions, and occasionally thin section work, are as far as analysis is taken, and it usually remains the preserve of more specialised, academic studies to attempt to undertake higher levels of characterisation, predominantly on account of the significant costs associated with further scientific work.

For limestones in particular, the primary stone type in the assemblage, there exist two standard classification systems, that of Folk, and that of Dunham.[329] The former is based around a distinction between calcite (sparry, crystalline) and micrite (lime mud) supported matrices (or a mixture of the two), complemented by descriptions of the allochems, i.e. "inclusions," present (including oolites, fossils, pellets, and intraclasts, i.e. rock fragments), and by noting the degree to which the texture is matrix- or grain-supported. The Dunham system is more inclusive, being less concerned with the identity of the allochems but instead being based on the degree to which the stone is matrix- or grain-supported, dividing limestones into mudstones (matrix-supported), wackestones, packstones and grainstones (grain-supported).[330]

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[328] Whitbread (1995); Quinn (2013).

[329] Folk (1959); (1962); Dunham (1962); Kendall and Flood (2011).

[330] Dunham (1962).

Seeking further detail about fabrics beyond the macroscopic, the two major areas for more precise analysis include methods better suited for establishing the identity and precise chemistry of the mineral inclusions, and methods for precisely measuring major, minor, and trace elemental chemistry, and isotope ratios, in bulk samples. Several techniques have been used, with the main approaches including inductively coupled plasma mass spectrometry (ICP-MS), X-ray fluorescence analysis (XRF), neutron activation analysis (NAA), proton-induced X-ray emission (PIXE), and scanning electron microscopy or electron microprobe analysis (SEM/EMPA).[331]

On a basic level, all of these techniques involve either the excitement of the sample with particles (in the cases of PIXE, NAA, and EMPA/SEM) or energy (in the case of XRF). The resulting secondary X-rays are measured to determine the chemical composition of the first few mm of the surface of the sample. ICP-MS involves the ionisation of a portion of the sample using a laser, the ions then separated using mass spectrometry and quantified; a similar technique is used for the analysis of stable isotopes, predominantly carbon and oxygen.

Portable XRF analysis (pXRF) has seen growing use, and is the particular technique being used by two other current British projects investigating Roman building material: Sara Machin at the University of Reading is using pXRF to analyse ceramic building material, particularly from the excavations at and in the vicinity of Silchester, and the Bournemouth University project *Building Roman Britain* is using the technique on stone and ceramic building materials from the palace at Fishbourne and the Roman Baths at Bath.[332] This method has the significant advantage of being non-destructive, and being usable on

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[331] For general overviews *cf.* Brothwell and Pollard (2001); Pollard *et al.* (2007); Pollard and Heron (2008). Examples of the use of these applications include: ICP-MS: Scarpelli *et al.* (2015); XRF: Capedri *et al.* (2000); NAA: Meloni *et al.* (2000); PIXE: Robertson *et al.* (2002); SEM: Tite *et al.* (1982).

[332] Building Roman Britain Project: URL = https://research.bournemouth.ac.uk/project/building-roman-britain/ (Accessed 2/12/17)

materials *in situ*. It does however have limitations, in having wider margins of error than other techniques, and a need for matrix-matched calibration standards. Furthermore results from uncleaned, exposed surfaces of archaeological material are likely to be contaminated by any patina or other residues sitting on the surface of the stone or ceramic.[333]

It seems a key facet of the nature of both stone and ceramic building materials that they are rarely homogeneous with regard to a number of characteristics. Regarding stone samples, as has been described above in Chapter 3.2.4 and in Catalogue 1, significant variation can exist across small expanses of a stone outcrop at the quarry, caused by variation in depositional processes and fluctuation in physical or biological activity in the sediments. Geological unconformities and faults can also create very sudden and dramatic changes of lithology. The same variation can occur in clay deposits, and any processing actions used on the clay, such as mixing, addition of temper, and firing, can all introduce further diversification of mineralogy and chemistry.

This fact was a key consideration when selecting analytical methods: whilst attributes such as bulk trace-element chemistry or stable isotope values can form a useful dimension to an overall characterisation, without a thorough knowledge or understanding of the degree of variation seen in both archaeological material and in the possible geological source material, these data are of limited use for comparison, even when multiple repeat measurements are taken. A high quality baseline geological dataset is not available against which to compare chemical data for rock and clays in this region. A more mineralogy and texture focused approach, involving qualitative observations, as opposed to a quantitative chemical programme, allows variation to be observed and understood in the sample, which is of more value when dealing with a heterogeneous material.

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[333] *Cf.* Liritzis and Zacharias (2011); Shugar (2013); Hunt and Speakman (2015).

Thus for this study thin section microscopy and scanning electron microscopy have been deemed to be most appropriate approaches. Mineralogical and textural observations were supported by data gathered with the use of the SEM's Energy Dispersive X-Ray Analyser (EDX), which provided semi-quantitative elemental characterisation of the sample. This technique does not offer the fully quantitative, trace-element analysis of other chemical techniques, but given the acknowledged variation within the material, comparison of major and some minor elements, enhanced by an understanding of the mineralogical variation affecting that chemistry, is far more insightful.

4.1.2 Analytical Methodology

4.1.2.1 Details and Character of the Assemblage

The building material assemblage which forms the central focus of this thesis has been collected in the course of ongoing research-oriented excavations at Dorchester on Thames, from a 30 m x 20 m trench located near to the centre of the enclosed area of the Roman small town (*cf*. Chapters 1.2.3 and 2.4.1).

The majority of the building material was found in secondary deposits, i.e. not in the location of its use, or even as collapses from a structure. Rather it is found throughout the trench in small quantities, spread through the accumulated layers, and highly fragmented, suggestive of the gradual discard of waste deemed no longer useable. The assemblage is very diverse in its character, showing a range of walling stone block sizes, types, and lithologies, a mixture of very different shapes and sizes of stone roofing material, and a broad array of CBM types and fabrics (predominantly *tegulae* and *imbrices*, with some box flue tiles and bricks). Despite the limited primary evidence for structures in the trench, given the broad variety of material, we can suggest that these fragments represent parts of different buildings from the vicinity. We can also see that the assemblage is very incomplete: no single type of material is present in particularly large quantities compared to the total amounts required even for single small buildings (*cf*. Chapter 2.5.2.). Given the date of deposition of most of this material, occurring in the late-Roman and post-Roman layers, we might conclude that we are seeing debris left-behind following the collapse of nearby structures, and considerable spoliation of material.

4.1.2.2. Hand Specimen Inspection

The first stage in running this study was the cataloguing of the building material, with the development of a catalogue system and sampling strategy necessary as an initial step.[334] Material was recorded in a database by box number, context number, number of fragments, total weight per context, and numbers of fragments of certain size. "Large" size was roughly defined as being fragments larger than 10 cm x 10 cm in top surface area, or greater than 200 g in weight; "medium" size was roughly defined as being fragments between 10 cm x 10 cm and 5 cm x 5 cm in top surface area, or between 100 g and 200 g in weight; and "small" size was defined as being fragments with a top surface area of less than 5 cm x 5 cm, or a weight of less than 100 g. Notes were also made in the database of whether form (e.g. *tegula*, *imbrex*, box-flue tile, stone roof tile) was identifiable, whether any interesting features, such as corners, *tegula* flanges or cutaways, or complete dimensions survived, and of any other significant features such as presence of markings, mortar, or nail holes, and whether there were any particularly distinctive fabrics or other notable features of that particular context assemblage.[335]

In the course of this initial cataloguing both stone and ceramic material was inspected with a hand lens. As discussed above, as a result of surveying the assemblage, it was decided that fabric analysis was to be the key analytical methodology used; very few examples of deliberate, interpretable markings were found on the material, and nor were

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[334] Mills (2013b) 20.

[335] *Cf*. the features of tiles as described by Brodribb (1987) 3, and the methodologies described by Orton, Tyers and Vince (1993) 57, and used by Warry (2006) 3, and Mills (2013b) 20-24.

a significant number of complete dimensions, intact tile ‘cutaways,’ or other morphological features identified.

During the hand specimen survey initial broad fabrics were identified and described for CBM according to colour, relative density of the fabric, texture, hardness, size, shape, and frequency of pores, and size, shape, frequency, regularity, and colour or identification of inclusions. For stone building materials fabrics were defined based on a judgement of stone type (as well as could be determined in hand specimen, colour, ‘inclusions,’ (i.e. particles or allochems), and the character of the matrix.

It should be noted that the use of colour as a diagnostic feature of particular fabric groups can be problematic, as for CBM, within a single firing of analogous clays, differential oxidising or reducing conditions across the kiln can result in different colours in the end products; with stone differing exposure to the elements or heat can also alter the surface colour of the material, and this characteristic is therefore treated with caution (*cf.* Chapter 4.2.1.5 and 4.2.2.1 below).[336] Similarly a certain degree of variation should be allowed within the categorisation of any given fabric: geological materials have natural variation, and in the case of CBM any modification made to the clay may not be absolutely consistent.

4.2.1.3. Light Microscopy

Following hand-specimen sorting, samples of both CBM and stone were selected for further analysis using binocular and polarised light microscopy. This step was undertaken to produce more detailed descriptions of the character of the material, and to test and refine the fabric groups identified during the first hand-specimen stage.

Samples seen as being representative of the main fabric groups identified in stage one were selected, and fresh broken edges of the material were created using a geological hammer

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[336] Chakrabarti, Yates and Lewry (1996).

in the first instance, and a wet-cutting diamond saw subsequently. This and the subsequent destructive methods of sampling were adjudged to be permissible given the detailed records being made and the large quantity of material in the archive; the roller-stamped tiles (see below) have not been sampled on account of their greater rarity.

Samples were inspected under x 10 magnification on a Leica Microsystems ES2 Stereo microscope. Notes were made of all general characteristics of the fabrics, using the higher magnification to better describe the frequency, shape, size, and possible identity of inclusions and the character of the matrix.

Following this step a subset of samples were chosen for preparation as standard 30 μm-thick thin sections (CBM by the Open University Thin Section Laboratory, stone by the University of Oxford School of Geography and the Environment). 19 CBM samples and 9 stone samples were selected for this analysis. Thin sections were inspected using a Nikon Optihot II polarising research microscope, according to the procedures set out by Whitbread and Quinn.[337]

4.2.1.4. Scanning Electron Microscopy

The final step of analysis, used for CBM samples but not stone samples, was their preparation for, and analysis by, scanning electron microscopy. This divergent approach to the two materials was chosen based on the differences between them, and the information desired. Stone was only considered in hand specimen and thin section because that was sufficient to furnish lithological information of enough detail and in a style facilitating comparison with published material. CBM was analysed using hand specimen, thin section, and SEM, firstly because clays have a far finer structure than limestones and sandstones, with far smaller particle sizes, making the use of the higher magnifications possible in the SEM (easily up to x 5000 and beyond, compared with x 400

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[337] Whitbread (1995); Quinn (2013).

on the optical microscope) of greater importance. Secondly, whilst archaeological building stone samples can quite easily be compared with the geological literature, the stone lithologically unchanged, a comparison between the fabric description of CBM and descriptions of raw clay in the geological literature is not straight-forward, the raw material having been processed and fired.

The SEM with EDX analysis gave the ability to analyse the broad chemistry of the clay bodies of samples, allowing the characterisation of the relative proportions of major and minor elements, reflecting the chemistry of the clay being used. Further it allowed the viewing of the major inclusions at greater magnification, it allowed them to be securely identified based on their chemistry, and it allowed the identification of smaller inclusions which were not visible in thin section. And finally the texture of the clay body, its porosity, and the interactions between the matrix and the inclusions could be observed with clarity at high magnification. All of these attributes facilitated the separating of fabrics and developing an understanding of the production of the CBM, building on the work done earlier in hand-specimen and on the microscope. 43 CBM samples were selected for SEM analysis.

The sample preparation procedure used was based on that of the Research Laboratory for Archaeology and the History of Art at the University of Oxford. Samples of roughly 1 cm^3 were first broken from the CBM fragments, and the edge chosen for analysis was ground flat by hand, using 120 grit silicon carbide abrasive grinding paper without a lubricant. The samples were then placed flat-side down in 3 cm diameter plastic moulds. The moulds were filled to c. 2 cm in depth with Struers CaldoFix-2 heat curing epoxy resin. The moulds were placed in a vacuum chamber and alternately pumped down to -1 bar of pressure for two minutes, and then gently re-pressurised. After five iterations of this process the samples were left in the vacuum at -1 bar for 1 hour. This method served to draw air from the outer edges of the porous fabric, allowing greater penetration of the resin. This was particularly important, as good penetration of the resin was necessary in order to facilitate a high quality polish. Following the vacuum process the moulds were placed in the oven at 75°C for 2 hours, before being removed and left to stand overnight: this enabled thorough curing of the epoxy resin, giving it improved mechanical properties that would allow a better polish without the disintegration of the sample.

The samples were then ground and polished. Grinding was achieved using a series of decreasing grit size silicon carbide abrasive papers: 180, 240, 320, and 600. Each sample was ground on each paper on a mechanical grinding wheel with running water for about 15 minutes at 100 rpm, or until scratches from the previous grinding were removed. The quality of the sample surface was regularly checked under the reflected light microscope to gauge this, and to ensure the samples were left with a good surface for polishing. Samples were polished using a diamond polishing system, again on a descending scale of abrasive-size: 9 µm diamond paper, 3 µm diamond paper, 1 µm diamond paste in a short nap cloth, and 0.25 µm diamond paste in a short nap cloth, all using a water-based lubricant. Samples were polished on the 9 µm paper for 20 minutes at 100 rpm, on the 3 µm paper for 15 minutes at 100 rpm, on the 1 µm cloth for 5 minutes at 150 rpm, and on the 0.25 µm cloth for 5 minutes at 150 rpm.

Samples were coated with a carbon coat, mounted using conducting carbon putty in an aluminium sample-holder, and earthed with adhesive copper tape. The samples were then analysed in a Jeol JSM 5910 scanning electron microscope in backscatter electron mode, chemical analyses carried out using an Oxford Instruments INCA Energy 300 energy dispersive analysis (EDX) system. Samples were analysed at 20kV, with a spot-size of 43 (equivalent to a current of 1.5 – 2 nA), and at a working distance of 10 mm.

Notes were made of the fabric texture, quartz abundance and size, porosity, and details of other aplastic inclusions (particles besides clay minerals, e.g. sand, small rock fragments etc.). The EDX analyser was used with Oxford Instruments' *INCA* software to obtain semi-quantitative chemical information on bulk areas of the fabric, for identifying individual inclusions, and X-ray maps were taken of regions of the sample, this function of the software allowing the production of false-colour images showing the presence and distribution of particular elements across the field of view. X-ray spectra for the spot and area analyses were collected over an acquisition time of 50 seconds, and 120 seconds for the element maps. Minerals were identified from the output X-ray energy spectra by comparison with standard rock-forming mineral formulae.[338] Data are reported as stoichiometric oxides, normalised to 100 % and recorded to one decimal place; multiple readings (at least 3) were taken for bulk area chemistry, at both lower (x 200) and higher (x 1300) magnifications.[339] Besides these data collected, multiple images of the fabric samples and inclusions at various magnifications were recorded. These allow side-by-side visual comparison between samples of the fabric micro-texture and inclusion size, shape, density, and distribution.

In order to provide a further factor by which to consider CBM fabric groups the chemical compositions of bulk areas of the clay body, as determined by SEM EDX, were tested statistically using agglomerative Hierarchical Cluster Analysis using Ward's minimum variance method: this statistical approach involves the progressive pairing of samples, and then clusters of samples, based on the match which minimises the total within-cluster variance.[340] Principal Component Analysis was also used to investigate whether any

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[338] Deer, Howie and Zussman (2013).

[339] *Cf.* Tite *et al.* (1982).

[340] Ward (1963).

significant differences occurred.[341] An overview of the methodology used for the analysis of CBM is presented in Fig. 4.1, with stone analysis halting after step 2.

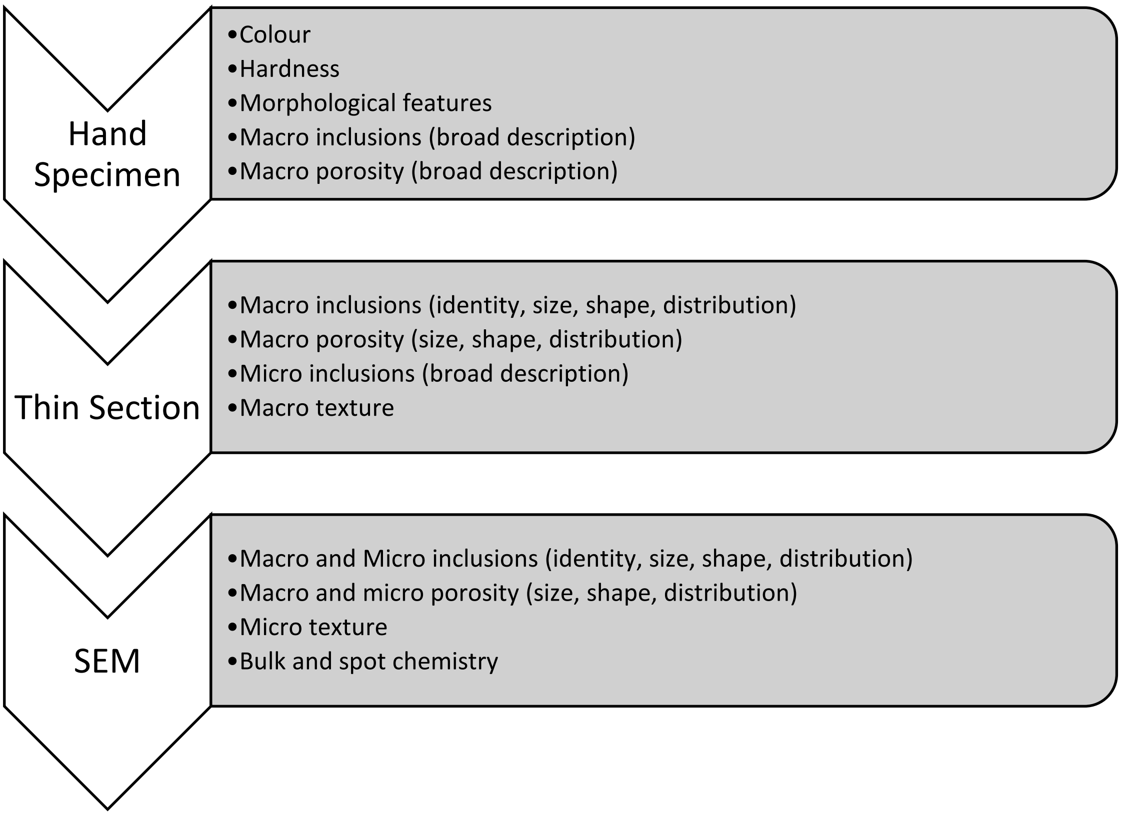

Figure 4. 1: Methodological process and observations from each step of the material analysis.

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[341] Baxter and Heyworth (1989).

4.2. Results and Discussion

4.2.1. CBM

The major outcomes of the CBM analyses can be divided into five categories: general observations about the assemblage in hand specimen; division of the assemblage into fabric groups; insight into the clays used; insight into clay processing; and insight into the firing process. A detailed catalogue of samples and the full results of the chemical analysis can be found in Catalogue 2.

4.2.1.1. The Assemblage

The initial round of cataloguing and hand-specimen examination of the CBM assemblage involved recording 5951 fragments, with a total weight of 300.36 kg, and an average fragment weight of 50 g. Of the three size-classifications defined above, 408 fragments were defined as large (> 10 cm x 10 cm, or > 200 g), 1412 as medium (5 cm x 5 cm – 10 cm x 10 cm, or 100 – 200 g), and 4131 as small (< 5 cm x 5 cm, or < 100 g).

The assemblage showed a fairly wide range of colours: reddish oranges dominated (the typical oxidised colour of many fired clays), but paler buff oranges, dark reds, bluish greys, reddish browns, and black pieces were all seen. In terms of CBM type, many pieces could not be positively identified, on account of simply being flat, having no morphological features to assist in the identification of the form. Of those which could be identified however, the vast majority were *tegulae*, recognisable by the presence of the flanges or lower or upper cutaways. *Imbrices* were the second most apparent form, recognisable by their curved shape, followed by box-flue tiles, recognisable by their combed exterior surfaces, sanded interior surfaces (sand applied to aid in the release of the clay from the mould; *tegulae*, *imbrices*, and bricks generally have sanded bottom surfaces), and thinner profile. Finally bricks seemed to be the least common form, although positive identification of a brick, as opposed to the bed of a *tegula*, is difficult. A thickness of greater than c. 40 mm was taken to be suggestive of a brick, although Roman bricks were often no thicker than a *tegula*; a lack of any indication of flanges or cutaways was treated as suggestive, but not definite proof, that the fragment was from a brick rather than a *tegula*; the latter also often preserved some trace of a finger-drawn “signature” or the flange, or even just a finger groove along the edge before the flange (if missing). The most complete fragment was an almost entire *imbrex*, broken into three pieces (Fig. 4.2). This measured 32 cm long (incomplete), 7.5 cm high, and 17 cm wide, at the complete wide end, and weighed 1.65 kg.

Figure 4. 2: Near complete imbrex from context 3703.

Tegula cutaways were occasionally in evidence, but given that this represents a thin, weak point of the tile, they were often broken and not fully identifiable to type. “Signatures” were relatively common, almost inevitably on the lower half of the upper face, and these usually took the form of a single or double semi-circle drawn with the finger. No other epigraphy or evidence of stamps were seen, except for the identification of seven fragments of roller-stamped flue tile. These specially marked box flue tiles have, as the name suggests, keying applied with a roller-stamp as opposed to a comb, and only a relatively small number of patterns are known.[342] These tiles are traditionally associated with the presence of *mansiones*, are generally dated to the late 1st or early and mid-2nd centuries AD, and are viewed as a relatively specialist production, some made by itinerant makers using the same stamp to make tiles in different locations with different fabrics, whilst others occur only in one fabric.[343] The three examples from this assemblage which were large enough and had enough detail to be definitively identified were of Stamp 35; unfortunately nothing is recorded about this stamp beyond its design (Fig. 4.3). Also within the total CBM assemblage were two tiles which had animal prints on them, one identifiable as a cat.[344]

Figure 4. 3: Fragment of roller-stamped flue-tile, identified as Stamp 35.

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[342] Betts *et al.* (1994); Mills (2013a) 460-2.
[343] Black (1985).
[344] *Cf.* Elliot (1991).

Other features of the assemblage included occasional evidence of tiles not held onto the roof simply by gravity and friction: there are several examples of nail or peg holes through *tegula* beds, sometimes made by piercing when the tile was still unfired, and some made by chipping a hole through the fired tile (presumably with some risk of breaking the tile); some fragments of *tegula* had mortar on their bases (not on more than one side, suggestive of use as rubble in a wall), suggesting that they were mortared onto the roof. It is possible that in both the pegged/nailed and mortared cases these were tiles at the bottom of the roof, overhanging the eaves, where friction was not sufficient to keep them on the roof.

4.2.1.2. Fabric Groups

The results of the hand-specimen inspections, thin section, and SEM analysis permitted the creation of fabric groups, splitting the assemblage into materially and technologically distinct sets. The creation of these groups was a highly complex procedure, involving a combination of textural, mineralogical and chemical information, often on a continuous scale of variation, and with many aspects of these categories' assessment being largely qualitative, or at best semi-quantitative. The sample naming convention was based on the fact that two runs of analyses were undertaken, the first using letters based on perceived fabric groups from hand specimen analysis; however, when it was realised that hand specimen observations did not prove entirely successful for fabric identification, in the second run context numbers were used. Some samples have a modifying initial: (G)A, indicates that this sample was thought to be of Fabric A, but had a *grey* core. Similarly (L)A indicated a *lighter* shade of reddish orange than was normal for that group. For samples named by context a decimal discriminates samples from the same context.

The results of this process are presented below in Table 4.1. Eight main fabrics were identified to which more than one analysed sample could be assigned, and a further 14 samples could not be placed into groups, and so should be seen as representative of fabrics on their own, making a total of 22 fabrics. The first eight are numbered one to eight, whilst the subsequent 14 retain the name of the sample by which they are illustrated.

Fabric	Colour	Feel	Inclusions	Clay Matrix	Porosity	Chemistry	Examples
1	Light or mid-orange, or a light bluey grey core with a light or mid-orange outer	Moderately hard to touch, but with slight friability.	Moderately abundant large sub-angular quartz; abundant small sub-rounded quartz; occasional small sub-angular potassium feldspar; occasional medium rounded iron oxide; TiO_2	Platey, low level of sintering	Few large rounded pores; frequent longitudinal pores between clay minerals	Low but not absent CaO (<1 %), but otherwise around the assemblage mean.	A4, A5, A6, A8, A9, P1, X1, X2
2	Dark or reddish orange	Hard to touch; sharp feeling fractures	Rare large sub-rounded quartz; moderately abundant small sub-rounded quartz; rare small potassium feldspar; TiO_2; ilmenite.	Relatively highly sintered, with smooth appearance	Moderately frequent large rounded pores; rare small rounded pores.	Low CaO (<1 %), relatively high FeO, slightly low Al_2O_3	B2, B3, B4
3	Mid-orange, or pale bluish grey	Moderately hard to touch	Rare large quartz; abundant small and very small angular quartz; frequent medium potassium feldspar; framboidal iron; biotite; ilmenite; TiO_2	Moderately sintered, still retaining some plateyness.	Moderately frequent large rounded pores; occasional small circular pores.	1-2 % CaO, generally lower Al_2O_3, high MgO	B1, B5, B6, 3471.2, 3471.5, 3658.1, 3658.3, 3658.4
4	Mid-orange with frequent cream and darker orange clay beads	Moderately hard to touch	Occasional large rounded quartz and potassium feldspar; moderately frequent small rounded quartz and iron oxides; TiO_2	Moderately sintered, some plateyness remaining.	Few pores.	Very Low CaO (< 0.5 %), relatively high TiO_2	A1, 3658.2
5	Dark brownish red outer with mid-bluish grey core.	Very hard to touch with sharp fracture	Moderately rare medium and large sub-angular quartz and potassium feldspar; moderate small rounded quartz; ilmenite; some very small iron	Highly sintered and vitrified; inclusions joining liquid phase	Frequent small and medium rounded pores	Very low CaO (< 0.5 %), high SiO_2, low Fe_2O_3, high K_2O	E1, 3199.1, 3213.2
6	Light to mid-orange outer with a mid-grey core. Or light orangey brown with a mid-grey core	Moderately soft to touch	Moderately abundant large sub-rounded quartz and iron oxide beads; moderate small sub-angular quartz and potassium feldspar; rare ilmenite and TiO_2	Moderately platey, but with smaller inclusions joining liquid phase	Some larger sub-rounded pores; few small longitudinal pores with plateyness.	Low CaO (1 %), high K_2O	3213.1, 3367.1

7	Mid-orange	Slightly soft to touch	Few large inclusions; rare medium sub-rounded potassium feldspar and quartz; moderately frequent angular small quartz and rare potassium feldspar; occasional TiO_2 and micas.	Closed, with no plateyness remaining, but frequent vitrification bubbles	Frequent small round vitrification pores	High CaO (4-6 %), low SiO_2, high FeO, high MgO	A7, 3152.2.
8	Pinkish orange and dark bluey grey	Slightly soft to touch	Very few large inclusions; rare medium and small quartz; grog temper.	Closed and partly vitrified	Rare large pores and abundant very small vitrification pores.	Very high CaO (10-11 %), low SiO_2	J1, 3152.1
3415.2	Brownish grey	Moderately hard	Moderately abundant large sub-angular quartz; abundant small sub-rounded quartz; occasional small sub-angular potassium feldspar; occasional medium rounded iron oxide; rare TiO_2 and ilmenite and micas	Moderately highly sintered with smooth connected surfaces of clay, but hints of plateyness remaining	Few large pores; moderately abundant small pores	1.2 % Cao; high FeO and K_2O	
3477.2	Light - mid yellowish orange	Soft	Highly abundant large sub angular quartz; moderately abundant small angular quartz	Highly sintered, but little sign of vitrification	Occasional small round pores, and occasional longitudinal cracks	2.5% CaO; high SiO_2 and Al_2O_3; very low FeO, low K_2O, low MgO, highest TiO_2	
3416.2	Dark reddish orange outer, to mid orange, to yellow, to mid bluish grey core.	Moderately soft	Occasional large sub-rounded quartz; abundant medium and small sub-angular quartz; potassium feldspar; rare TiO_2	Linearly organised; platey, but with some signs of slight vitrification	Few small sub-rounded pores	1.6% CaO, but otherwise around the assemblage mean.	
3416.4	Mid-orange outer, to yellow, to light bluish grey core.	Soft	Moderately abundant medium and small angular quartz; quite frequent small potassium feldspar; micas and ilmenite; bone fragments	Quite smooth and closed; highly sintered	Occasional small round pores	High CaO (7.5%), but otherwise around the assemblage mean.	
3416.1	Dark orange	Moderately soft	Rare large rounded quartz; moderately abundant medium rounded quartz and potassium feldspar; abundant small angular quartz; some micas and TiO_2	Closed, highly sintered	Few medium rounded pores	1.6% CaO, high FeO, Al_2O_3 and TiO_2	
M1	Light brownish yellow	Soft	Very few large inclusions; abundant small angular quartz; occasional biotite	Highly sintered	Few large longitudinal pores	1.9% CaO, high SiO_2, low FeO	
3152.3	Dark orange	Moderately hard	Moderately abundant large rounded quartz and potassium feldspar; abundant medium and small angular quartz; occasional micas; some ilmenite and TiO_2	Platey	Occasional large round and longitudinal pores	CaO 1.3%, but otherwise around the assemblage mean.	

A3	Light to mid-orange	Moderately hard	Moderately abundant large medium and small quartz; rare potassium feldspar; occasional iron oxide beads	Very highly sintered, with inclusions starting to join liquid phase; some platyness remaining	Rare large longitudinal pores	1.2% CaO, but otherwise around the assemblage mean.	
A2	Light to mid-orange	Moderately hard	Moderately abundant large medium and small quartz; moderately abundant medium potassium feldspar; moderately abundant iron inclusions, ilmenite, and TiO_2	Relatively smooth, highly sintered matrix, with hints of plateyness	Occasional longitudinal pores	1% CaO, high FeO	
3416.3	Grey outer with a reddish orange core	Moderately soft	Abundant large rounded or sub-rounded quartz; occasional large potassium feldspar; frequent iron oxides and some TiO_2	Smooth, highly sintered or even vitrified	Frequent large and small rounded pores	0.8% CaO, very high FeO, low MgO, Al_2O_3, and K_2O	
3477.1	Mid-yellowish orange	Moderately soft	Rare large inclusions; abundant small angular quartz and potassium feldspar; occasional iron oxides and micas; bone and occasional calcite	Not highly sintered, fired to a low temperature	Occasional large and medium rounded pores	4% CaO, low FeO	
3671.1	Yellowish orange to orange	Soft	Occasional very large sub-angular composite quartz grains; small and medium potassium feldspar; plagioclase feldspar (albite); chlorite; calcite	Moderately sintered	Occasional large rounded pores	Very high CaO (11.5%), low SiO_2 and Al_2O_3	
3471.3	Light creamy orange	Soft	Occasional large rounded quartz; calcareous inclusions; occasional ilmenite	Vitrified and bubbly	Frequent tiny round pores and occasional large round pores	Very high CaO (15.9%), low SiO_2	
3471.1	Yellowish brown outer with a light orange core	Moderately hard	Moderately abundant medium angular quartz and potassium feldspar; TiO_2; bone fragment and large angular grog	Vitrified honeycomb texture	Frequent small rounded pores	High CaO (12%), low SiO_2 and Al_2O_3	

Table 4. 1: CBM Fabric Groups

The following were the major factors which assisted in the creation of the fabric groups. Firstly, the general observations and descriptions from hand-specimen and thin section were used to create the initial fabric groupings, based on macro texture and major inclusions clearly observable in magnifications of up to x 400. These descriptions can be found in Catalogue 2.1. Secondly, through SEM analysis, these fabric groupings were refined based on inclusion identity, size (roughly, Very Large = greater than 500 μm; Large = 100 – 500 μm; Medium = 50 – 100 μm; Small = 10 – 50 μm; Very small = less than 10 μm), and shape (rounded, sub rounded, sub angular, angular, or longitudinal), and clay body microtexture. Finally, the chemistry of sherds gave a further dimension through which to compare samples. These three main discriminators, inclusions, microtexture, and chemistry, will be discussed further here.

Inclusions

Quartz was present, and was the most common crystalline mineral, in all samples, and it was seen in all shapes and sizes across the assemblage (Fig. 4.4). After this potassium feldspar was the second most common, present in most samples, again seen in very large down to very small sizes (Fig. 4.5). Iron oxides were also very common in practically all samples, sometimes as discrete mineral inclusions (probably haematite), and sometimes simply as streaks or beads of iron-rich clay. Very occasional framboids were seen (roughly spherical aggregates of microcrystallites), particularly in Fabric 3; these were probably originally of pyrite, FeS_2, although sulphide ions were not detected by the EDX due to oxidation during firing to haematite (Fig. 4.6). Most samples also contained titanium dioxides (probably rutile), iron-titanium oxides (ilmenite), and zircon, generally as very small specks throughout the clay. In some fabrics mica species were seen, particularly biotite but also muscovite, sometimes in relatively significant quantities (Fig. 4.7). Chlorite, epidote, and pyroxenes were also observed in some samples, as occasionally were other feldspars, including albite, the plagioclase feldspar sodium endmember (Fig. 4.8).

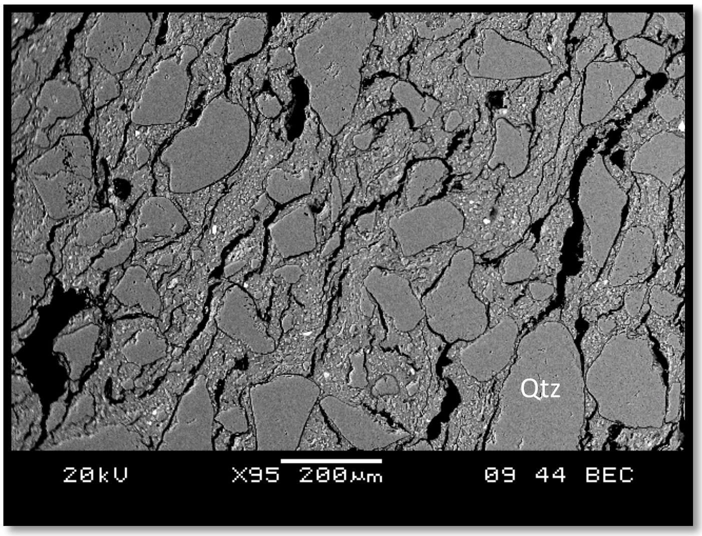

Figure 4. 4: Quartz grains of various shapes and sizes. Sample 3477.2, backscattered electron image.

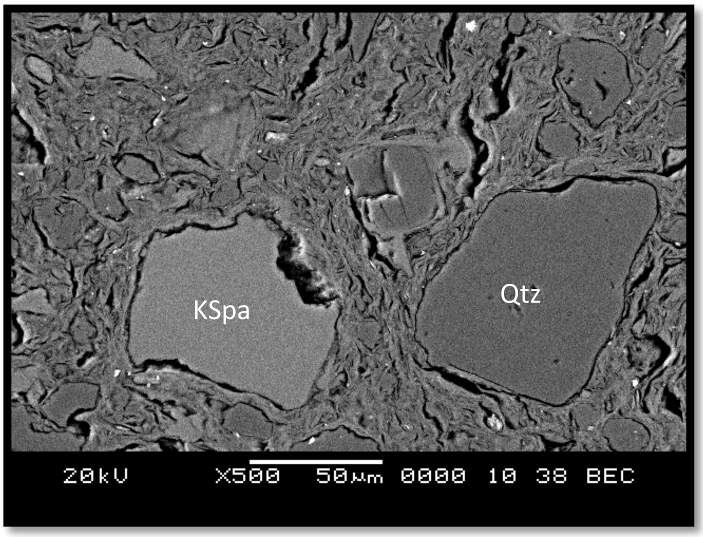

Figure 4. 5: Potassium feldspar grain. Sample A2, backscattered electron image.

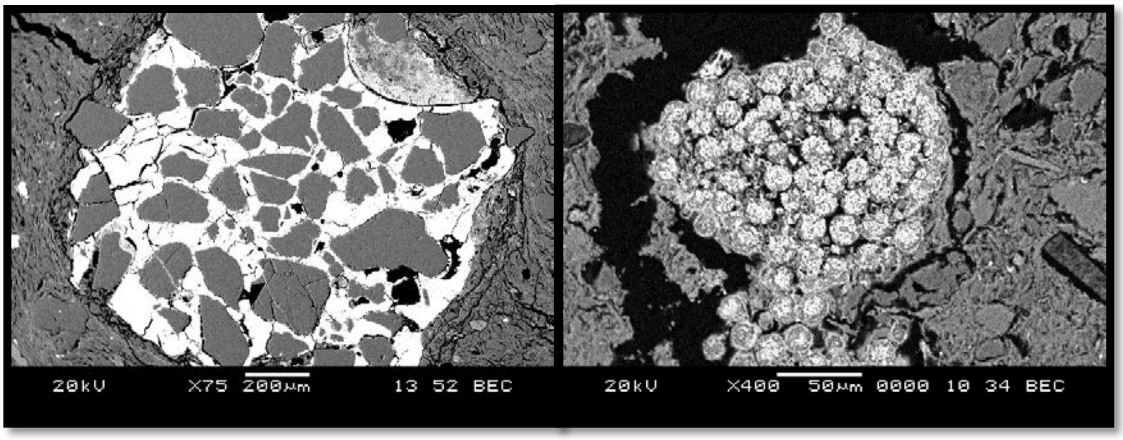

Figure 4. 6: Iron rich matrix with quartz inclusions (L, Sample 3416.2), and framboidal iron (Sample B5), backscattered electron images.

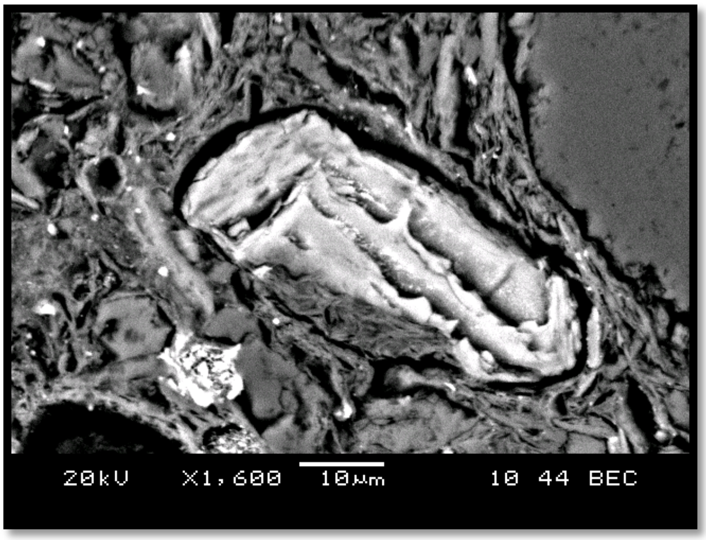

Figure 4. 7: Biotite. Sample 3658.1 in backscattered electron image.

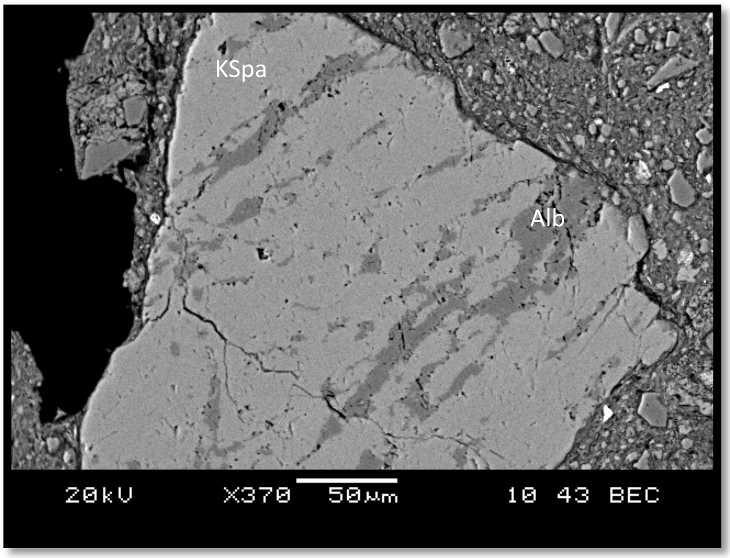

Figure 4. 8: Perthite – intergrowth of albite in potassium feldspar. Sample 3671.1 in backscattered electron image.

Across the entire assemblage there was only relatively limited variation in mineral species, with few particularly 'exotic' minerals, indicative of a relatively limited range of fabric types made from clays formed in a limited range of environments with similar material input. The majority of the assemblage's inclusions reflect the expected mineral species input into the Jurassic and early Cretaceous bedrock clays of the region, which were formed by the erosion of metamorphic and igneous rocks of the London-Brabant Massif (*cf.* Catalogue 1). However, in spite of the general species-consistency through a majority of samples, significant differences were still observable between samples in terms of both inclusion identity and in size, shape, and frequency, reflecting several diverse clay sources or processing practices in use. For example, Fabrics 1 and 2, both of which show quartz, potassium feldspar, iron oxides, titanium dioxides, and ilmenite, are split predominantly on the basis that Fabric 1 contains a significant quantity of large and very large rounded quartz grains, whilst these are absent from Fabric 2 (Fig. 4.9). It is likely that these represent a temper, discussed further below (Chapter 4.2.1.4).

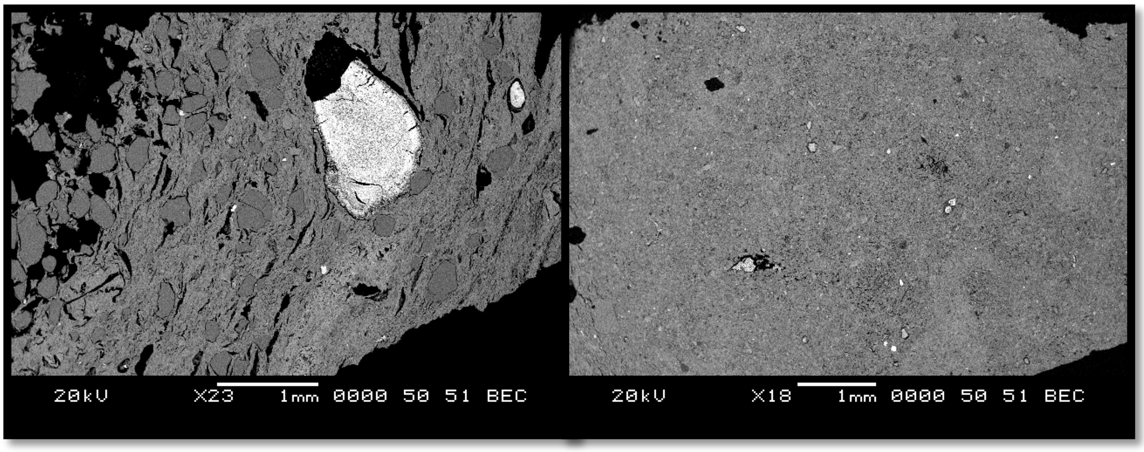

Figure 4. 9: Fabric 1 (L, Sample X2) and Fabric 2 (Sample B5), in backscattered electron images, showing highly divergent major inclusion size and frequency.

Several more diverse fabrics are seen: Sample 3477.1 is a good example of a mineral assemblage notably different from that seen in Fabrics 1 and 2, containing frequent calcite inclusions as well as abundant micas (Fig. 4.10). This represents a very different clay source, and given the mixed inclusion shapes and sizes, perhaps the use of alluvial clay, as will be discussed further in Chapter 4.2.1.3.

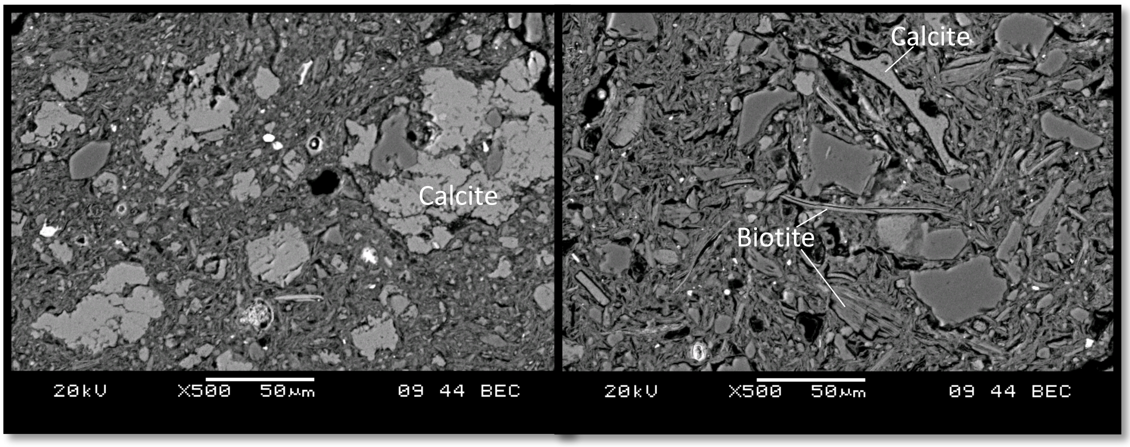

Figure 4. 10: Two backscattered electron images of Sample 3477.1, showing calcite, biotite, and bone fragments.

Clay matrix

The texture and porosity of the clay matrix, and its interaction with inclusions, was another means by which fabrics could be separated, largely concerned with the degree of sintering (the bonding of clay minerals together, but without a glass phase forming) and the degree of vitrification (the bonding of clay minerals through the formation of a glass phase). Matrices ranged from highly platey, loosely sintered examples, through to vitrified bodies showing an extensive liquid phase. In the former the clay minerals and inclusions maintained distinct boundaries, showing little or only limited interaction (Fig. 4.11 L). At the more vitrified end of the spectrum the matrix had a much smoother appearance, as a result of the clay minerals, and even some of the major inclusions (especially quartz and potassium feldspar) participating in the development of the liquid phase, dissolving in the melt and becoming combined into a continuously bonded surface (Fig. 4.11 R). Less sintered matrices generally presented many interlinked longitudinal pores, left behind by the clay minerals shrinking apart from each other; more vitrified matrices generally presented more rounded pores, created by decomposition gases being trapped by the glass phase.[345] What we can learn from these different states of matrix will be discussed more below (Chapter 4.2.1.3-5).

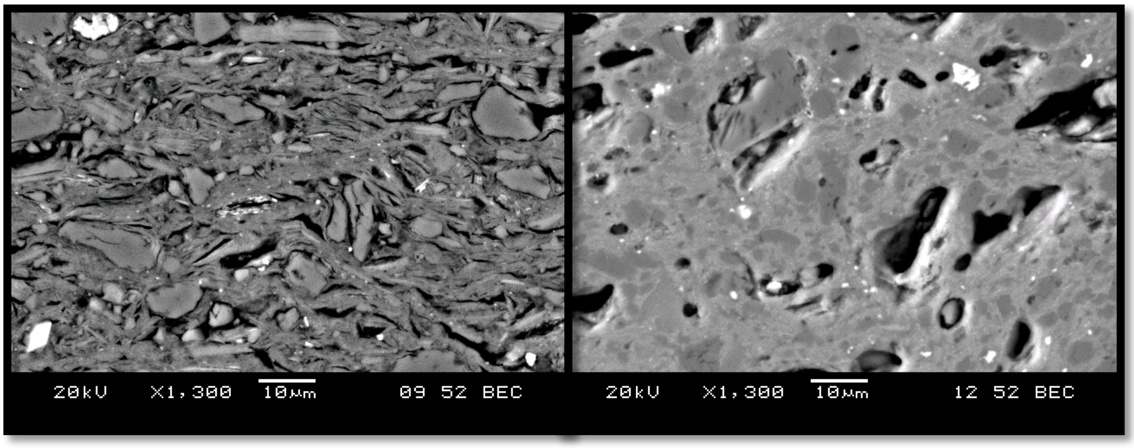

Figure 4. 11: Differing levels of vitrification in the clay matrices of Samples 3152.3 (L) and 3416.3.

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[345] Tite *et al.* (1982) 109-110.

Chemistry

The relative proportions of different elements in a sample can be very useful for dividing samples into fabric groups. Full data are presented in Catalogue 2.2, reported as compound weight percentages calculated by stoichiometry as oxides, and normalised to 100 % on account of the high porosity of some samples.[346] It should be noted that SEM EDX analysis provides only semi-quantitative values for major and minor elements in a sample (over 0.1 % by weight in ideal conditions). Data were thus reported to one decimal place. NaO and PO_4 were excluded from the analysis because of detection in only a limited number of samples.

Across the assemblage variation was relatively limited, with the key statistics presented in Table 4.2.

	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
Mean	64.6	19.7	2.6	6.8	3.6	1.9	0.9
Std. Dev.	3.9	1.6	3.8	1.2	0.8	0.7	0.3
Coefficient of Variation (%)	6.0	8.0	146.3	17.6	21.1	0.3	0.2
Minimum value	54.5	16.6	0.0	1.7	0.2	3.6	2.1
Maximum Value	71.6	23.5	16.0	9.1	5.0	39.7	31.6

Table 4. 2: Key statistics from the EDX analysis of the CBM assemblage.

Patterns can be explored in the data through statistical analysis. On a simple level, mean and standard deviation are useful for highlighting outliers, and generating an understanding of how much variation there is in the assemblage. The oxide with the greatest coefficient of variation, i.e. the highest standard deviation in relation to its mean, calculated as a percentage, is CaO by some way, making this the variable which splits the assemblage the most. In these samples the main source of CaO is most likely to be

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[346] This is a standard procedure: *cf.* Tite (1992).

crystalline calcite or micrite (e.g. in Sample 3477.1, Fig. 4.12 above). Immediately the assemblage can essentially be split into two groups – those made from calcareous clay and those made from non-calcareous clay, a distinction discussed further below (Chapter 4.2.1.3.).

Iron and potassium oxide stand as the next most variable components, and, together with MgO and TiO_2, played an influential role in the determination of fabric groups. The proportions of these oxides mostly reflects varying quantities of minor inclusions, encompassing iron oxides, tectosilicates (such as feldspars), inosilicates (such as pyroxenes), and phyllosilicates (clay minerals, micas, and chlorite). Thus Sample A8, with one of the highest FeO contents, can be seen to have frequent iron rich beads in its matrix in thin section macrograph, represented by optically opaque reddish black specks (Fig. 4.12).

Figure 4. 12: Sample A8, thin section macrograph, with frequent dark reddish black iron oxide beads.

Hierarchical Cluster Analysis (HCA), carried out using Ward's Method, and Principal Component Analysis were carried out on the dataset to explore what a purely statistical approach, not taking into account other knowledge, would show. The dendrogram produced by the HCA divided the assemblage into five groups based on pairing samples by chemistry with the aim of minimising variance with each pairing (Fig. 4.13). 3477.2 is left on its own, based on its outlying chemistry: it has the highest SiO_2, Al_2O_3, and TiO_2 values of the assemblage, and the lowest FeO. It seems very likely that this tile was made from a clay markedly different from any used for other samples.

The four remaining groups overlap somewhat with the fabric groups set out above: the blue group corresponds partially with Fabric 1, with Samples A5, A6, A8, A9, and X2 falling within both. However, the yellow and green groups do not seem to agree closely with the remaining samples or fabric groups. This is most probably because of the relatively consistent chemical compositions of many of these samples, all stemming from similar clays and with similar inclusions. The fourth group however, in pink, corresponds to the six most calcareous samples, including the two belonging to Fabric 8.

As an alternative approach to the Hierarchical Cluster Analysis, Principal Component Analysis was also conducted (Fig. 4.14). In this image the colours used were those from the groups created by the HCA plot above, and, as one would expect, broadly similar clusters appear using this technique. Principal Components 1 and 2 account for 61.3 % of the total variation/Eigenvalue within the assemblage. Fig. 4.15 illustrates the contributions different oxides make to Components 1 and 2, and therefore the factors determining in which directions samples are pulled on the plot. Principal Component 1 is largely determined by silicon, magnesium, and iron, with some effect from titanium and potassium, whilst Principal Component 2 is mostly determined by calcium and silicon.

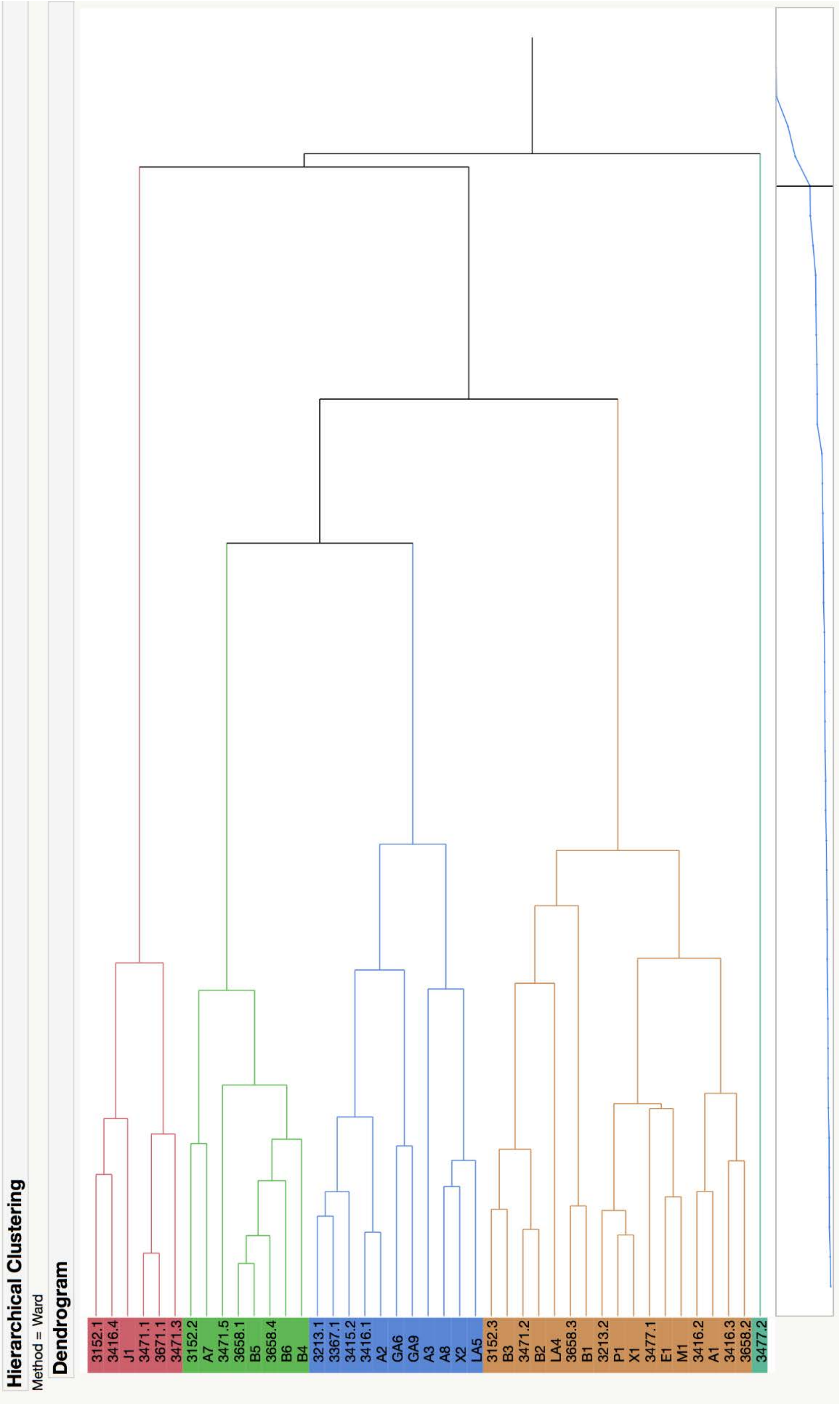

Figure 4. 13: Dendrogram plot of Hierarchical Cluster Analysis carried out using Ward's Method.

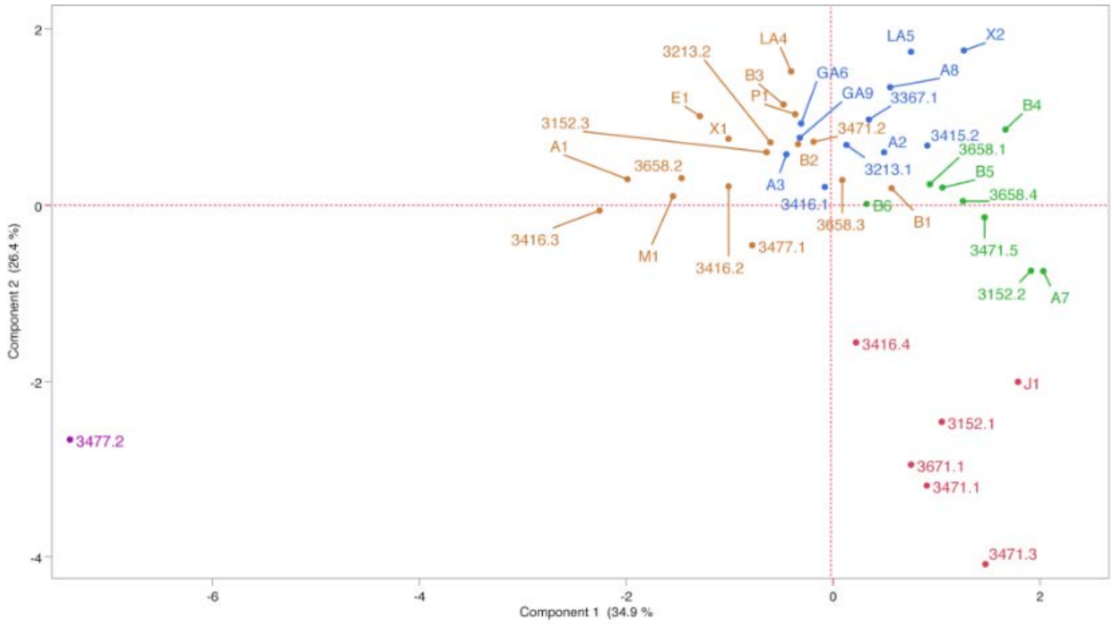

Figure 4. 14: Principal Component Analysis plot of the assemblage, samples coloured per the groups created by HCA.

Again 3477.2 appears as a complete outlier. Group 4, in red, falls in the south east quadrant, pulled there by their calcium content, and they appear not to be a particularly close cluster, something borne out by a closer look at the chemistry, inclusion, and textural characterisation of these samples. The remaining samples, as expected cluster untidily near the centre of the plot with significant overlap, and this goes some way to explaining the incongruence between the groups created by HCA and the fabric groups proposed above.

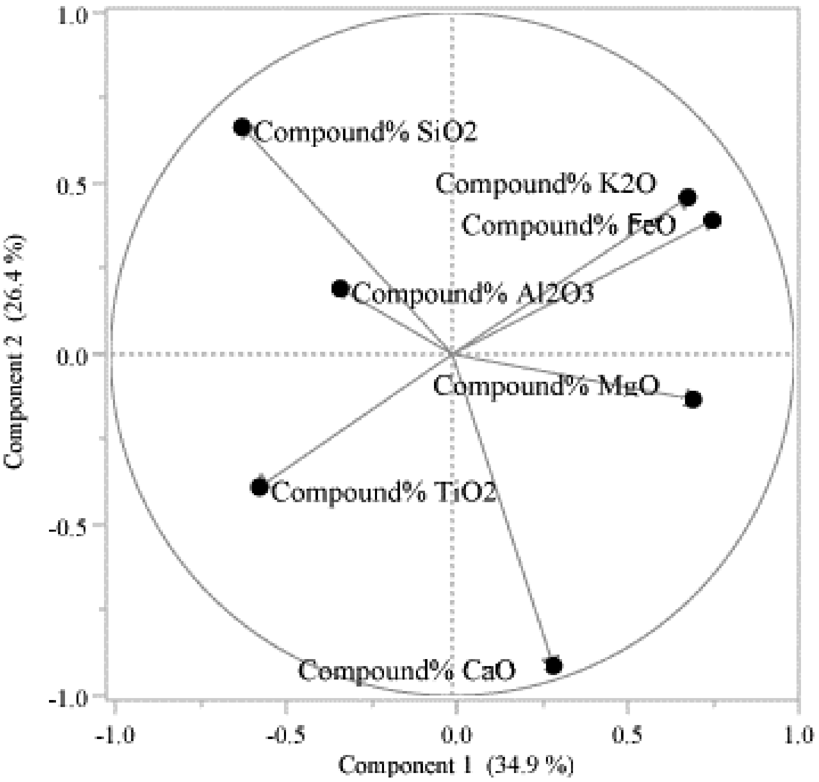

Figure 4. 15: Illustration of the spatial contribution of the different oxides to Principal Components 1 and 2.

This exercise therefore goes to demonstrate the need to consider all aspects of the characterisation of samples in order to understand the real differences between them. The relatively limited variety in inclusions seen across the assemblage ensures relatively little variation in sample chemistry, and thus statistical approaches to splitting samples into fabrics are only of limited functionality.

A good illustrative example of the need for this approach considering all variables is a comparison between Samples A1, 3416.2, and 3416.3. These are three samples which, simply listed, all contain the same basic inclusions (quartz, potassium feldspar, iron oxides, and titanium dioxides), and have very similar chemistry, coming out as direct neighbours in the hierarchical cluster analysis: on these factors alone these samples might be seen as being of the same fabric. However, a look at the relative proportions of mineral inclusions, their sizes, shapes, and distributions, and a description of the microtexture of the clay body, show that these are in fact very different pieces of CBM, but that the statistical analysis of their chemistry within the assemblage was not able to detect this (Fig. 4.16).

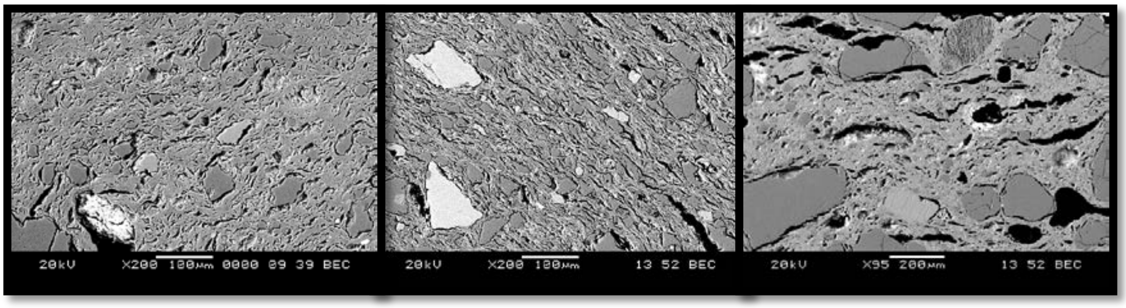

Figure 4. 16: Samples A1 (L, x200), 3416.2 (x200), and 3416.3 (R, x95) in backscattered electron images, illustrating highly variable fabric textures and inclusions despite similar bulk chemistry.

A1 is characterised by moderately abundant small, medium, and large quartz crystals and small potassium feldspar crystals, generally sub-angular in shape, set into a somewhat closed, platey clay matrix; 3416.2 has very few large quartz crystals, the fabric dominated by common small and medium sub-rounded quartz crystals and common medium angular potassium feldspar crystals set in a very platey, linearly arranged matrix; 3416.3 on the other hand is dominated by very common large and very large rounded quartz crystals (so large that in the image above this sample is displayed at a much lower magnification than the other two samples), with small and medium quartz crystals below this in the process of vitrifying into the matrix, the potassium feldspars also far along the process of degradation, and the matrix itself highly sintered, smooth, with frequent rounded pores.

As emphasised recently by Ian Betts at a conference, the first stage in any analysis should involve actually looking at the samples, rather than just "zapping them with our toys" (said in reference to pXRF analysis).[347]

4.2.1.3. Types of Clay Used

The limited range of inclusion species seen across the majority of the assemblage is suggestive that in most cases we are dealing with a clay created by relatively consistent formation processes. The most likely setting for this is in the extremely low energy environment to be found at the bottom of a shallow sea, where minerals will be

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[347] Betts *pers. comm.* Building Roman Britain Conference, Bath, UK, 10.11.2017.

fractionated over a very long period of time by size, weight, and species. This would therefore suggest that the dominant fabrics were most likely to have been made from maritime bedrock clays, such as the Oxford, Kimmeridge, and Gault Formations (Catalogue 1).

As discussed in Catalogue 1, alluvial or glacial clays would be expected to have far coarser mineralogies, most likely with a greater range of mineral types reflecting surface geologies rather than those of the London-Brabant Massif, now deeply buried. Thus lower levels of potassium feldspar might be expected in these superficial deposits, for example. In addition larger and more angular inclusions may also be present, due to the higher energy environments in which they formed and the shorter period of transportation and thus fractionation and abrasion through which they went. 3152.3 might be one example of a tile made from alluvial clay. It has a large quartz fraction, probably an added temper (see below, 4.2.1.4, and Catalogue 2.1), but relatively low potassium oxide levels, reflecting low frequency of potassium feldspar. In the size range of between 5 and 50 µm, the fabric is characterised by very mixed inclusions, in terms of size, shape, and identity (Fig. 4.17). Many pieces were highly angular, and showed little organisation or common orientation, suggestive of a high energy deposition. This sample also seems to contain a very high ratio of inclusions to clay, appearing almost to be a clayey silt, rather than a silty clay. This presents a significant contrast to the far more consistent, ordered inclusions and clay body of the more common fabrics, for example A4 in Fabric 1.

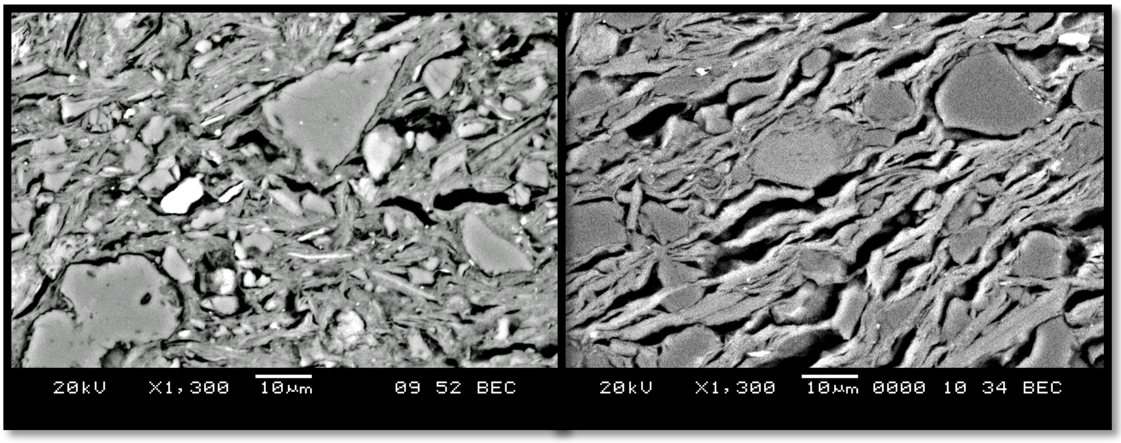

Figure 4. 17: Sample 3152.3 (L) and A4, 3152.3 possibly made from an alluvial clay, whilst A4 is almost certainly made from a bedrock marine clay.

Samples 3416.1 and 3477.1 are two other candidates for having been made from alluvial clays, with similar disordered inclusions of varying species, shapes, and sizes (Fig. 4.18).

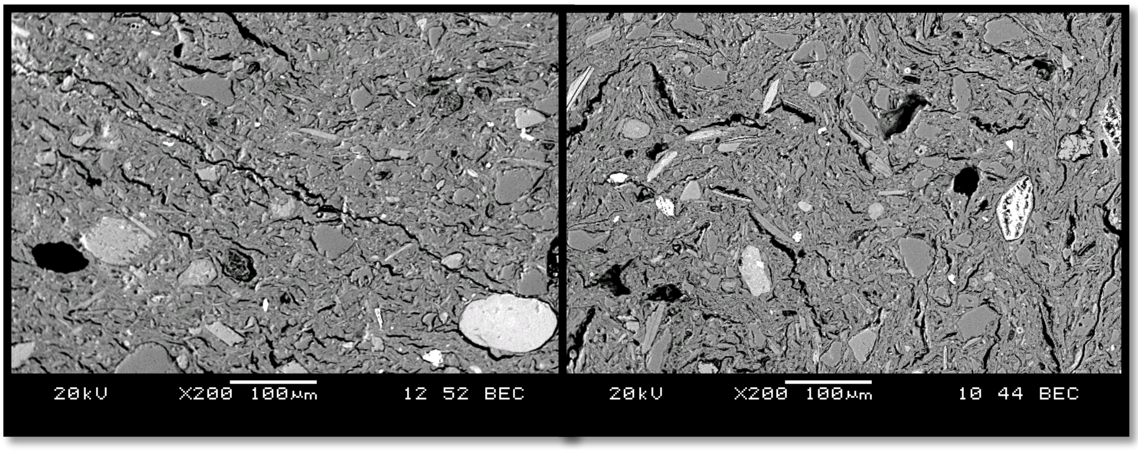

Figure 4. 18: Samples 3416.1 (L) and 3477.1., two other possible candidates for production from alluvial clay, rather than marine clay.

A further comment to be made on clay types concerns the use of calcareous and non-calcareous clays. It is noteworthy that calcareous clays are not at all common, with only 5 samples possessing CaO concentrations of 10 % or over (J1, 3152.1, 3671.1, 3471.3, and 3471.1) and only a further two above 5 % (A7 and 3416.4), the standard threshold for definition as a calcareous clay.[348] Calcareous clays might be used because the calcite, to some degree, acts as a flux, lowering the sintering temperature of a clay, therefore producing a denser body from a shorter and lower temperature firing.[349] Clearly this might be an advantage in

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[348] Albero Santacreu (2014) 63.

[349] Tite and Maniatis (1975) 19; Heimann (2016) 336.

reducing the fuel costs for firing the very large volumes of clay involved in CBM production. In samples J1, 3152.1, 3471.3, and 3471.1 significant vitrification textures have been formed, presumably the result of the lowered sintering temperatures of the clay (Fig. 4.19). The bubbles are still small, perhaps reflecting calcite also acting as a buffer, protecting the clay from over-firing if the kiln was not well controlled.[350] Sample 3671.1 does not display this pattern of rounded pores, with a very closed, non-porous, sintered matrix (*cf.* images in Catalogue 2.1). This might be on account of a lower firing temperature, and will be discussed further below (Chapter 4.2.1.5). It is of course also possible that there was no technological or functional advantage sought in the use of calcareous clays, and this could simply reflect what was available, or perhaps the aim for a particular preferred fired colour, something also discussed further below (Chapter 4.2.1.5).

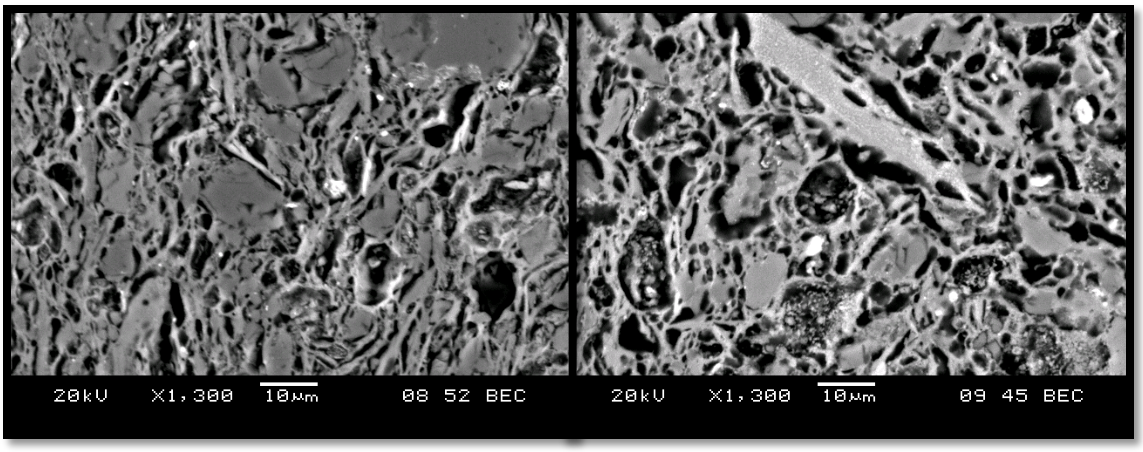

Figure 4. 19: Samples 3471.1 (L) and 3152.1, backscattered electron images, showing highly vitrified microtextures in two calcareous fabrics.

In sum, it is apparent that several different clay sources, of different types, are being used to supply the town. Romano-British Dorchester's tile-makers seem to have used both bedrock and alluvial clays, as well as both calcareous and non-calcareous clays, with the attendant variation in clay performance during forming and firing, which will have necessitated variation in preparation and firing procedures.

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[350] Maniatis and Tite (1981).

4.2.1.4. Clay Preparation and Processing

The primary clay preparation procedures apparent in this analysis are the processes of mixing clays and of the addition of temper. Both of these processes were common in historical pottery production, crucial for obtaining the right balance of plasticity during forming, performance during firing, and physical characteristics in the finished vessel. Whether CBM producers took similar steps has not been clearly discussed before for Roman CBM production. As Degryse and Braekmans note, it can often be very difficult to judge whether variation across a sherd might be the result of natural heterogeneity in the clay source or the result of human actions.[351]

Clay Mixing

This is most apparent when two clays with clearly different optical properties have not been thoroughly mixed, leaving variation of colour across a sample in hand specimen (sometimes quite subtle, and not to be confused with oxidation or reduction patterns), or in differing optical properties observable in a thin section. A further means by which mixing might be identified is through a disparity in inclusion type, size, or frequency across a sample.

Examples of what might be clay mixing can be observed in the scanned thin sections of samples A1, A4, A5, A8, and B3, as well as in SEM micrographs (Fig. 4.20).

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[351] Degryse and Braekmans (2016) 254.

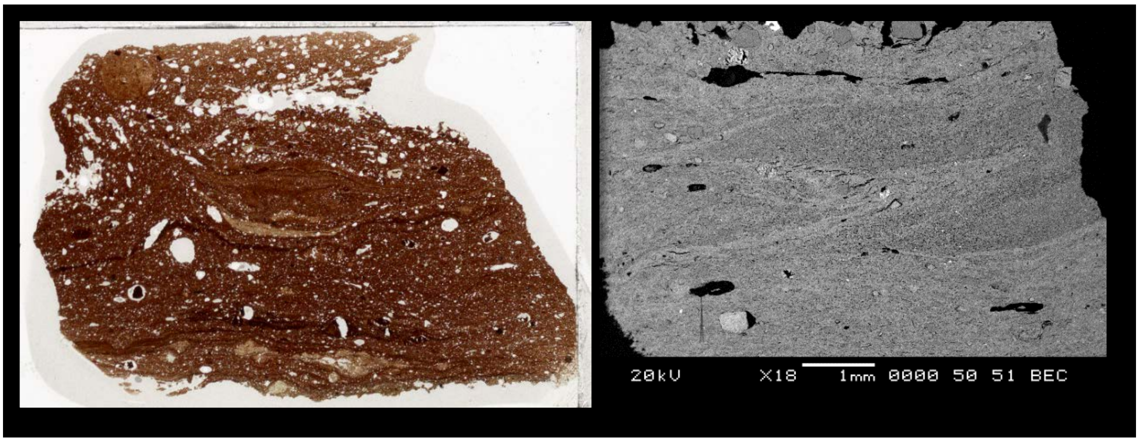

Figure 4. 20: Thin section macrograph and backscattered electron micrograph of Sample B3. Sample height in thin section is c. 2.5 cm.

The varying colours seen in the example of B3 might offer some suggestion of the variation in composition of these clays: the pale cream colours may be the result of increased calcite; the darker blackish red streaks may result from increased iron oxide content. As noted, this mixing may simply be the result of natural variation in the raw clay, or may be deliberate: the addition of a calcareous and iron rich clay would conceivably provide fluxes for reducing the sintering temperature, as discussed above. B3 certainly has a relatively highly sintered matrix.

Tempering

The act of tempering is also most obvious when the added material is not thoroughly mixed into the clay, leaving an uneven distribution through the sample. Alternatively bimodal grain size distributions might be suggestive of the addition of temper. It should again be noted that there is inevitably some uncertainty when it comes to identifying these features: clay deposits might often contain alternating bands of finer clay and coarser sandier clay as a result of changing depositional conditions. Uneven mixing of these varying grades of clay during processing might create uneven sorting of inclusions through the piece, and might naturally introduce a bimodal grain size distribution.

However, examples can be seen in the assemblage which appear suggestive of tempering. The distinction between Fabrics 1 and 2, for example, rests somewhat on the apparent use of sand temper in Fabric 1, and the absence of its use in Fabric 2. Both Fabrics 1 and 2 had a fraction of small quartz crystals, c. 10 – 50 μm in size, interpreted as being the natural silt present in the clay, but of the two only Fabric 1 also had a fraction of large quartz crystals, between c. 100 and 400 μm in size (Fig. 4.21). These, as can be seen below, were not evenly mixed throughout the sherd, with subtle clusters or strings, showing that the temper was not thoroughly mixed through the clay.

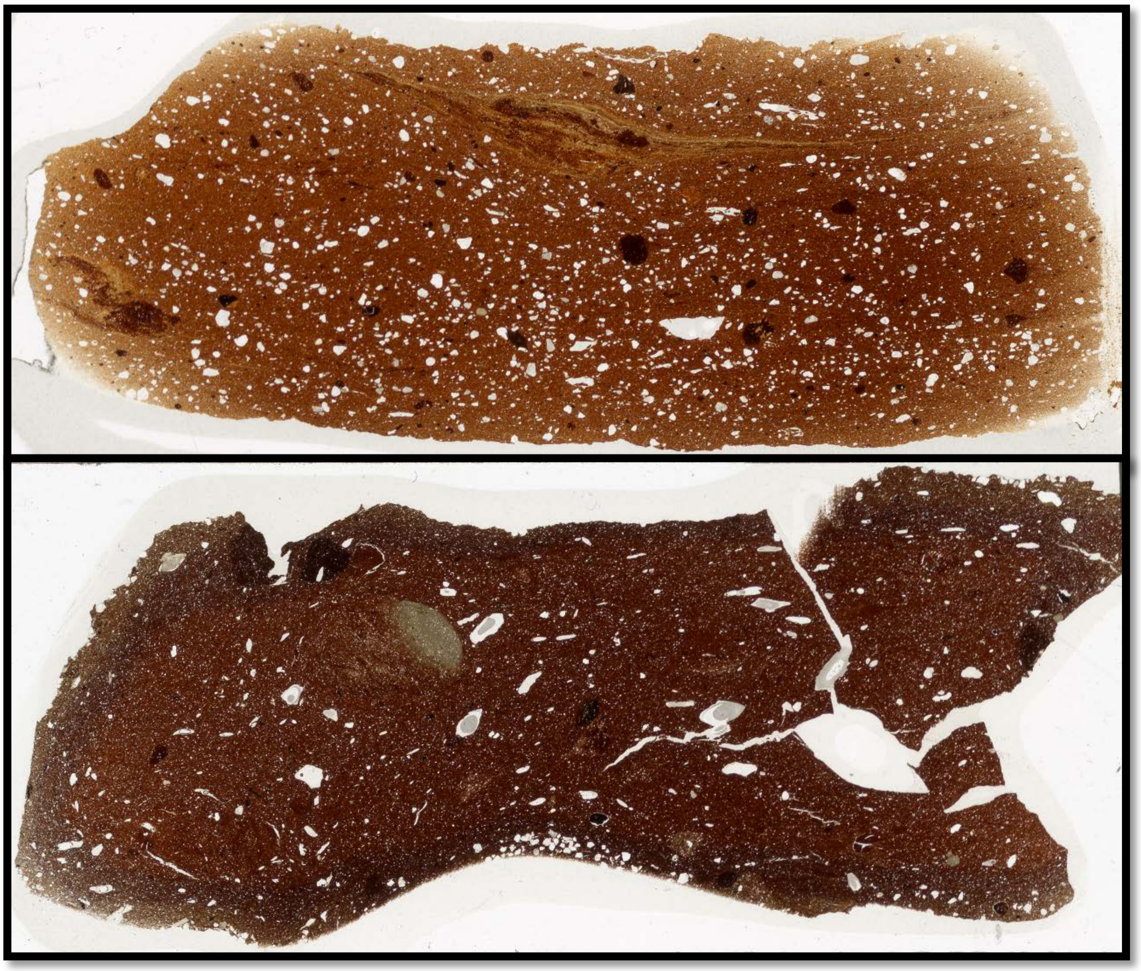

Figure 4. 21: Samples A5 (top) and B1 in thin section macrograph.

Some examples of Fabric 2, whilst lacking this larger quartz fraction throughout the clay matrix, did show isolated regions with large sand particles, often close to one edge of the tile, usually the bottom, as can be seen in the image of B1 above. Samples B3, B5, and B6 also show this pattern: this sand might be interpreted as having been used for aiding the release of the wet clay from the mould or board with which it was formed, pressed into the clay during the forming process. This practice of using sand to stop the clay sticking is clear from the "sanded" bottom surfaces of most CBM on site, and ethnographic evidence showing continuation of this practice into the modern period.[352]

Other samples show a similarly suggestive pattern of strongly bimodal inclusion distributions, including Sample X1 and Sample 3415.2 (Fig. 4.22). In both of these cases the larger sand-sized inclusions are relatively well-sorted throughout the sherd, and so some doubt has to be acknowledged as to whether this represents a well-homogenised temper or simply a natural bimodal distribution throughout the clay.

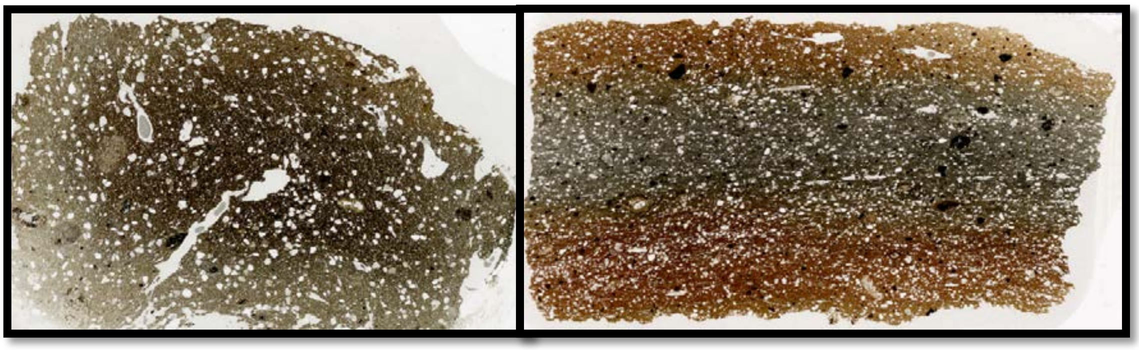

Figure 4. 22: Samples 3415.2 (L) and X1 in thin section macrograph.

A special case when it comes to tempering is the use, not of quartz, but of already fired ceramic pieces, known as 'grog,' in order to improve the qualities of the fabric.[353] This usually involved the use of crushed pottery or CBM. It is of course possible for crushed ceramic to end up in a fabric accidentally, and frequently clay beads, probably simply the dried scraps from the maker's hands, end up in fabrics, and so these two caveats must be borne in mind. Grog might be recognised principally as separate angular fragments within the matrix (with clay beads tending to be rounded in shape).

Three examples of grog use in separate fabrics were seen in the Dorchester assemblage: Sample J1, 3152.1, and 3471.1, shown in Figs. 4.23-25. J1 is shown in hand-specimen, with

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[352] E.g. Istituto Luce (1951) 2:15.
[353] Whitbread (1986).

grog pieces apparent from their generally paler colour and non-interaction with the surrounding matrix; 3471.1 is shown in thin section micrograph, with the angular grog pieces clear from their darker red or black colour and higher frequency of quartz inclusions than the surrounding clay; and 3152.1 is shown in a backscattered electron image, with a piece of grog clear from its non-interaction with the surrounding clay and greater density of inclusions.

Figure 4. 23: Sample J1 in hand specimen.

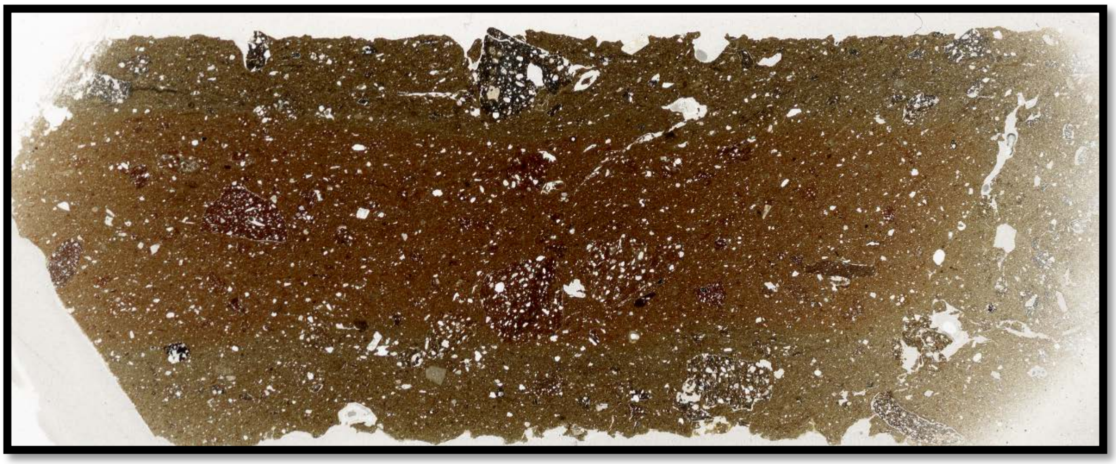

Figure 4. 24: Sample 3471.1 in thin section macrograph.

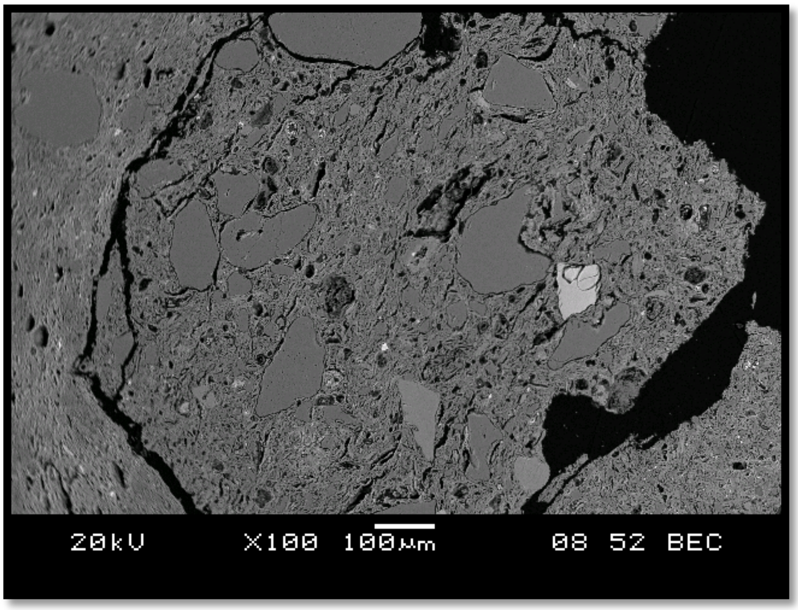

Figure 4. 25: Sample 3152.1 in backscattered electron image, with a grog inclusion clear.

4.2.1.5. Clay Firing

Atmosphere and Colour

The first question to consider here is what the colours of hand-specimen samples demonstrate regarding cycles of oxidation and reduction in the course of firing.[354] The basic procedure for any wood-fired kiln starts with an initial, lower temperature stage of oxidation of metal oxides in the ceramics, as at these lower temperatures complete combustion of the fuel occurs, producing little carbon monoxide.[355] As the temperature in the kiln rises above 700 °C, if there is inadequate air flow to the fuel (estimated at being an excess of over 50 % more than that theoretically required for complete combustion of carbon), incomplete combustion of the fuel begins, producing less and less carbon dioxide and more carbon monoxide.[356] This creates a reducing atmosphere in the kiln which causes iron to be altered from higher to lower oxidation states, i.e. the conversion of Fe^{3+} to Fe^{2+}, red coloured Fe_2O_3 to grey-black FeO. This state could be created purposefully by sealing up the kiln, or might simply occur as a result of the increased incomplete

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[354] *Cf.* Velde and Druc (1999) 5.6 and 5.7 for a discussion of the oxidation and reduction of iron ions in clay during firing.
[355] Dawson and Kent (1999) 165-166.
[356] Mellor (1914b) 35-42.

combustion that occurs naturally at higher temperatures. If however there is sufficient excess of air complete combustion can continue and the oxidising atmosphere is maintained (potentially altering the metals in metal oxides from lower to higher electron charges). As Bryant and others have shown, even once active firing has ceased it is possible for an alteration in the kiln atmosphere to affect the ceramics: if the kiln is sealed, having been operating with a reducing atmosphere, then the reduced state of the ceramic will be maintained, but opening the kiln to air will re-oxidise the exposed surfaces.[357]

The majority of sherds in the Dorchester CBM assemblage are in a mid-orange colour throughout, indicative of the presence of Fe_2O_3, i.e. Fe^{3+}, a more oxidised form of iron which appears a reddish orange. This indicates either the maintenance of an oxidising atmosphere throughout the firing, i.e. with plenty of airflow to the fuel, or, more likely perhaps, a naturally reducing atmosphere during the active stages of firing, before an extended period of cooling with intakes into the kiln opened to allow re-oxidation of the pieces throughout their whole thickness. Worrall states that in clays with relatively high iron oxide contents (5 – 9 %), and relatively low aluminium oxide contents (10 – 22 %), and negligible calcium oxide, a description which would fit many of these examples, that "all shades of red are obtained, the shade darkening as the firing temperature is raised."[358] Examples of this include A1, B4, and 3152.2, amongst many others (Fig. 4.26).

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[357] Bryant (1971).

[358] Worrall (1986) 84.

Figure 4. 26: Sample A5 in hand specimen, fully oxidised to a mid-orange colour.

This is in contrast to samples with grey cores and orange exteriors, such as A6, A9, X1 and X2 (Fig. 4.27). The grey core shows that the pieces were fully reduced during firing, but at the end were allowed to partially re-oxidise during cooling. That the re-oxidation did not penetrate the entire thickness of the fragment may indicate slightly more rapid cooling, halting the reaction. The zoning seen in 3152.1, from a pale orange exterior, to a light bluish grey, to a darker bluish grey in the core, may also be the result of this process.

Figure 4. 27: Sample A6 in hand specimen, with a reduced grey core and oxidised orange outer.

We then come to the rather more interesting oxidation and reduction patterns seen in some sherds. 3499.1 has a brownish red core before a thin grey stripe, and then mid-orange surfaces (Fig. 28). The large iron oxide beads visible in this sample also show interesting patterns in terms of oxidation and reduction, those in the core being red, whilst those in the grey band are black. A hypothesis for how these strips were produced is that the piece was initially fired in an oxidising atmosphere, which became reducing as the temperature increased. This began to reduce the iron in the piece from the outside inwards, but was stopped short of fully reducing the core, and the piece was briefly oxidised again at the very end of firing, but cooled rapidly so that this oxidation did not penetrate far into the tile. The red colour of the iron oxide beads in the centre, and black of those in the grey bands, support this hypothesis, representing oxidised Fe_2O_3 in the core and reduced FeO in the grey portion of the fragment.[359]

Figure 4. 28: Sample 3499.1 in hand specimen, showing several different states of oxidation or reduction through its core.

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[359] Rye (1981) 117.

3416.2 shows a slightly different pattern, with a grey core, a band of yellow, then a band of light orange, before a band of darker reddish orange on the surfaces (Fig. 4.29). A possible explanation for this piece is a simple reduction firing, turning the whole piece grey. This was then followed by a period of re-oxidation during cooling, but that this was only long enough to re-oxidise different depths of the piece to different degrees. One step of oxidation of the grey black FeO might create a yellow coloured layer of Fe_3O_4, a mixture of Fe^{2+} and Fe^{3+}, according to Dawson and Kent, whilst the outer surface was able to reach full oxidation to Fe_2O_3, giving the orange and red colours.

Figure 4. 29: Sample 3416.2 in hand specimen, showing a complex sequence of changing core colours.

Sample 3416.3 is notable for having a dark orangey red colour throughout, except for a thin band of dark bluey grey (Fig. 4.30). One possible explanation for this might be that the bottom of the tile ended up sat in ash, and so after a normal reduction firing, when the rest of the tile re-oxidised during cooling, the reaction was not able to occur in the part sealed by ash.

Figure 4. 30: Sample 3416.3 in hand specimen, showing thin band of reduced iron oxide on one surface.

Finally we should consider the effect of calcareous clays on the firing colour. Samples 3471.1, 3471.3 and 3671.1 all have a calcium oxide to iron oxide ratio of roughly 2 : 1 or more, and this is apparent from the fired colour, these samples having pinkish yellow and cream colours (Fig. 4.31).[360]

Figure 4. 31: Sample 3471.3 in hand specimen, showing the pinkish buff colour characteristic of oxidised calcareous fabrics.

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[360] Worrall (1986) 85.

Factors such as thickness of samples, the openness of the fabric, and the position in the kiln will all have had an impact on fired colour, and from a single firing not all products will have had the same final appearance due to variation in these factors. As noted above, technofunctional interpretations of colour do not tell the full story, and a social explanation for the colours obtained must also be considered, i.e. the reddish oranges which dominate may be the generally preferred target colour, or certain variations may have been associated with products of different workshops, carrying connotations of prestige perhaps.

Temperature and Time

It is worth noting first of all that, as Tite *et al.* state, there is perhaps only limited value in attempting to estimate with any great precision the firing temperature of ceramics.[361] Experimental firings have shown that temperatures across a small Roman-style pottery kiln can vary by as much as 100 or 150 °C, and in essence we already know that we are considering a range of temperatures of c. 800 to 1100°C, this being the region in which earthenwares are fired to the solidity necessary for CBM.[362] In addition it should be noted that, for understanding the ultimate character of a ceramic, time duration of firing is also influential, and indeed every variable, from clay and inclusion chemistry to fuel type, will affect the phase changes through which it goes: firing clay produced a very complex series of reactions. The indications of firing temperature visible through the SEM mineralogical and textural analysis will be considered here. Predominant amongst these is the state of sintering of the fabric, but the condition of mineral inclusions, particularly quartz and potassium feldspar, also speaks of relatively high firing.

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[361] Tite *et al.* (1982) 112-113.

[362] Tite *et al.* (1982) 113; Simpson (1997) 52.

Samples which appear to have been less highly fired, or fired for a shorter soak time, include much of Fabric 1, as well as one or two other examples such as 3416.2 and 3471.2. At lower temperatures the individual minerals in the paste remain far more discrete, including both the clay minerals, appearing in SEM images with a platey texture, and the quartz and potassium feldspar inclusions, even when small, maintaining clear boundaries from the clay body. Examples include Sample A1 and 3471.2, as seen in Fig. 4.32. It seems likely that these pieces were fired to a relatively low temperature, perhaps just 800 – 850 °C, with A1 less highly fired than 3471.2. These lower fired pieces also have a less hard feel to them in hand specimen, being softer, leaving more dust with handling, and being easier to break or saw during sample preparation.

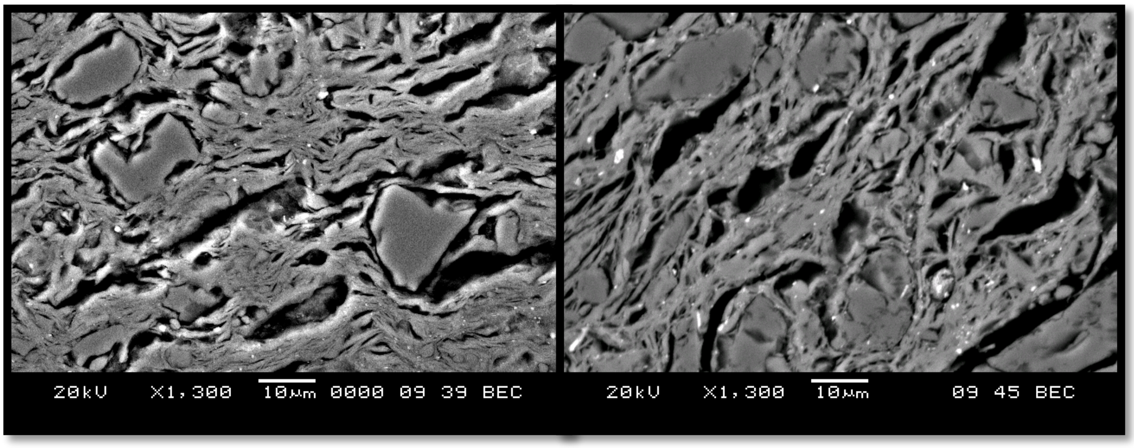

Figure 4. 32: Samples A1 (L) and 3471.2 in backscattered electron images, showing relatively platey, only moderately sintered textures, reflective of a relatively low maximum firing temperature.

At higher firing temperatures the clay minerals begin to sinter together more, forming larger continuous surfaces, and, beginning with the smaller ones, inclusions start to become involved in the growing liquid phase. This presents as a smoother looking more closed texture, and with increasing temperatures the boundaries between the clay and the inclusions become ever more indistinct. With increasing vitrification smaller and then larger bubbles, seen as rounded pores, begin to appear, the result of the liquid phase becoming continuous and viscous enough to trap any gases evolved from mineral decomposition reactions in the paste.[363]

Examples of this beginning to be happen, where the fabric has become viscous and closed enough to trap gases, but where a full glass phase has not been formed, resulting in a still somewhat platey looking fabric with distinct inclusions but with very small round pores, include Samples A7 and 3416.4 (Fig. 4.33).

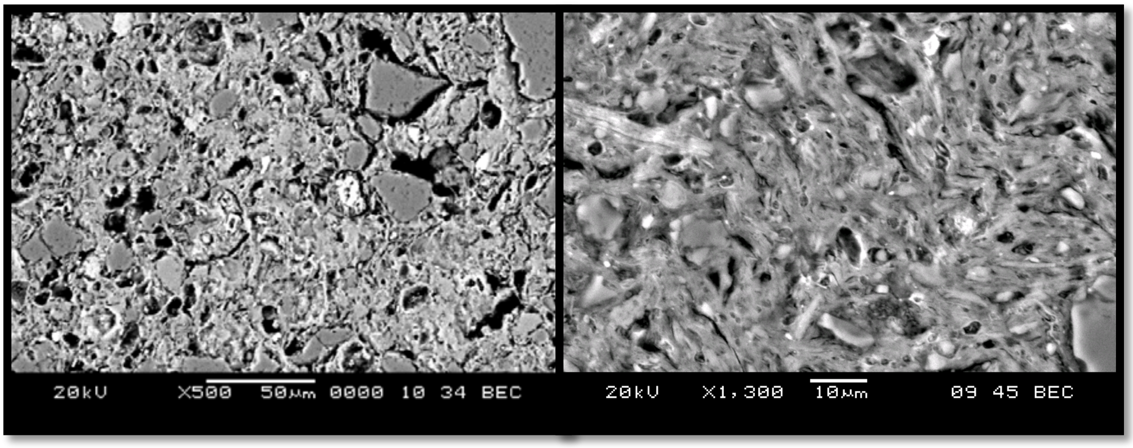

Figure 4. 33: Samples A7 (L, x500) and 3416.4 (x1300) in backscattered electron images, showing more highly sintered clay minerals and the formation of small gas bubbles beginning.

Examples showing greater temperature or longer soak times, resulting in the even more closer, smoother clay body and melting inclusions, include samples in Fabric 2, such as Sample B2, and others including 3416.3 (Fig. 4.34).

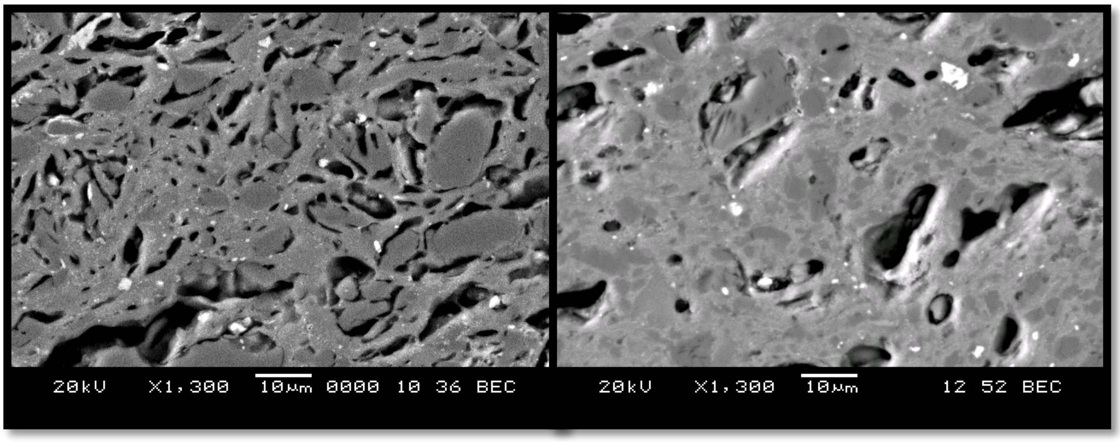

Figure 4. 34: Samples B2 (L) and 3416.3 in backscattered electron images showing extensive vitrification textures and the melting of smaller quartz inclusions.

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[363] Maniatis and Tite (1975) 229.

Samples 3199.1, 3213.2, and E1, all identified as Fabric 5, have been more highly fired than most samples, and this can be detected immediately in hand specimen, the tiles having a very hard feel with sharp edges, and they were noticeably more difficult to break or saw during sample preparation. A close look at the texture of the core of sample 3199.1 in thin section shows many small round or sub-rounded pores (Fig. 4.35: pores appear grey; quartz crystals appear white), and these are also clear in the SEM images of Samples E1 and 3213.2, on both a macro and micro scale within the fabric (Fig. 4.36).

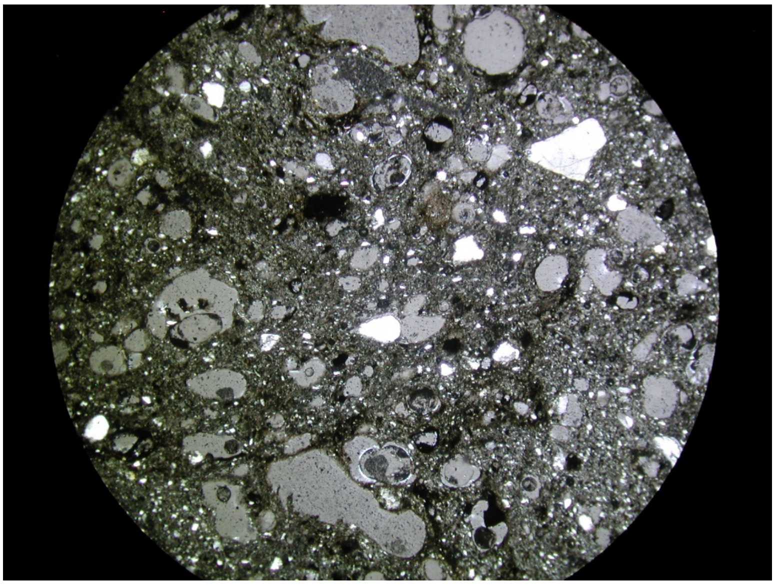

Figure 4. 35: Sample 3199.1 in thin section micrograph in xpl with multiple rounded and sub-rounded pores.

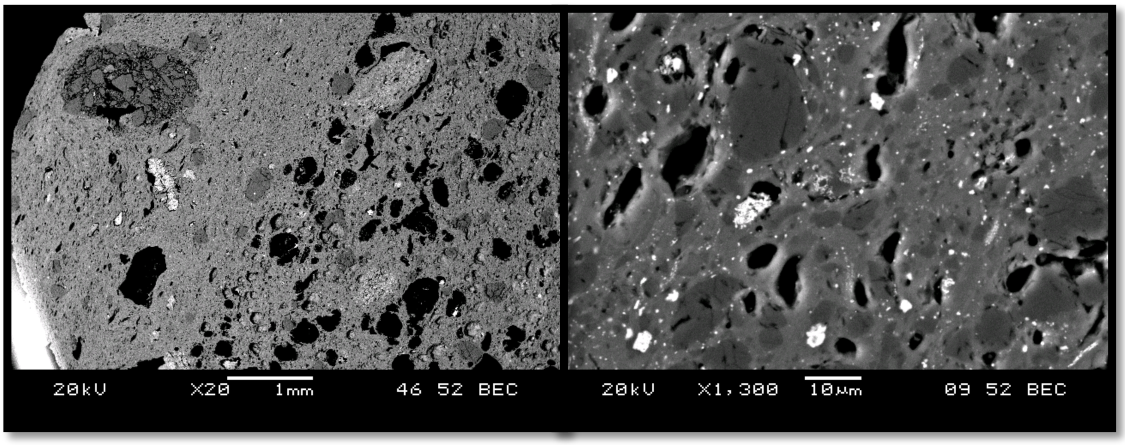

Figure 4. 36: Sample 3213.2 in backscattered electron images at x20 and x1300 magnification showing multiple rounded and sub-rounded pores.

The smaller quartz crystals in the fabric appear very tightly combined with the clay matrix around them, practically continuous with it, as a result of the initiation of their melting (as seen in the image of 3213.2 in Fig. 4.37, below), and potassium feldspar crystals can be seen to be breaking down (as seen in the bottom right corner of the image of E1, below). As noted above it is difficult, and perhaps not that informative, to make estimations of firing temperatures, but given the characteristics of this fabric, and its non-calcareous nature, we would certainly expect this fabric to have been rather highly fired, perhaps to more than 900 °C: Heimann notes that potassium feldspar is stable until that temperature.[364]

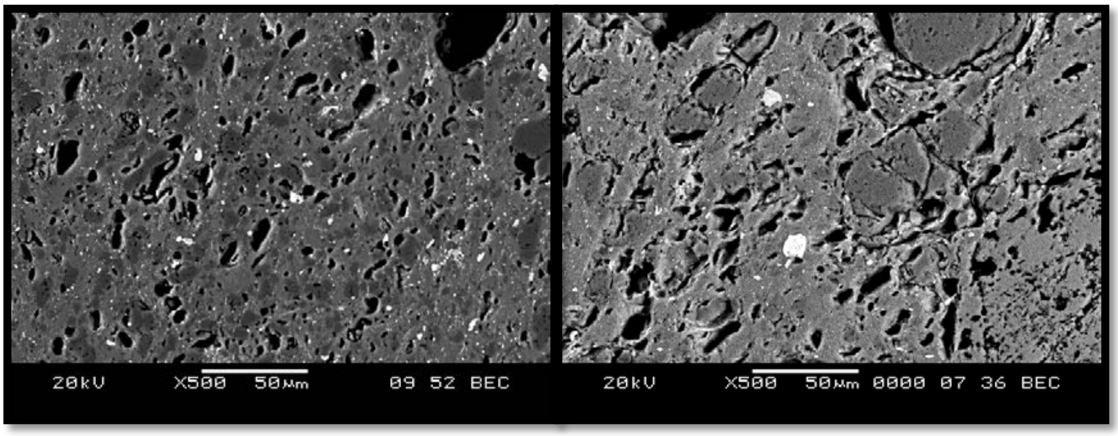

Figure 4. 37: Samples 3213.2 (L) and E1 in SEM backscattered electron images showing the melting and decomposition of quartz and potassium feldspar crystals.

In sum, this CBM assemblage shows considerable variation, in clays used, processing actions taken, and in firing conditions. Some of these may represent deliberate choices made by different producers, whilst others may simply represent natural variation in the raw material, in the actions of the maker, and in the temperature and atmosphere of the kiln. Allowing for this it still seems however that over the course of Dorchester's Roman history it would appear that diverse material sources were exploited for the construction of roofs in the town, perhaps more than might have been expected for such a small settlement. The implications of this will be discussed further below (Chapters 5 and 7).

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[364] Heimann (1982) 90.

4.2.2. Stone

On the whole there is rather less that can be discussed regarding the stone, it being a chemically unaltered natural material. The discussion is here divided into two sections, firstly the observations from the assemblage in hand specimen, and then secondly the observations based on thin section microscopy of a sub-sample of the assemblage.

4.2.2.1. The Assemblage

The initial round of cataloguing and hand-specimen examination of the stone building material assemblage involved recording 2681 fragments, with a total weight of 170.67 kg, and an average fragment weight of 64 g. Of the three size-classifications outlined above (Chapter 4.1.2.2), 213 fragments were defined as large, 439 as medium, and 2029 as small.[365]

It should be noted here that the archived assemblage of stone is likely not to be entirely representative of all the stone that was found on the site: during the early years of excavation there was no specific interest in the question of building materials, and so whilst larger lumps (often shapeless) of limestone and flint can be seen in site photographs, these were not kept and added to the finds archive, presumably because they were thought of as being too bulky, heavy, and of limited interest. Every season large lumps of stone are found discarded on the trench edges and not collected with context information. Thus only the smaller, thinner, lighter pieces of stone may have made it into the assemblage. These are problems faced far more often by building materials, and particularly stone, than other material types such as pottery or animal bone. The fact that the only naturally occurring stone in the direct vicinity of the site is easy-to-recognise river gravel means that any and all other pieces of stone were explicitly transported by man to the location, but the natural appearance of stone may make inexperienced or unaware

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[365] See 4.1.2.1. above: “Large” is defined as roughly 10 cm x 10 cm in top surface area, or greater than 200 g in weight; “medium” size was roughly defined as being fragments between 10 cm x 10 cm and 5 cm x 5 cm in top surface area, or between 100 g and 200 g in weight; and “small” size was defined as being fragments with a top surface area of less than 5 cm x 5 cm, or a weight of less than 100 g.

excavators discard it, thinking of it simply as a natural component of the soil rather than as an artefact.

Of the assemblage which was collected, however, flat pieces of stone dominate, the majority of them presumed to be pieces of broken roof tile. Thicknesses of these ranged from c. 10 mm up to c. 30 mm. The largest fragments weighed up to about 0.8 kg, but no pieces were complete or had entire intact length or breadth dimensions. The majority of the material was of a white, grey, cream, or yellowish colour, with a small proportion of pink fragments. The majority of this was viewed, through examination in hand-specimen and with a loupe, as limestones, some highly oolitic, some shelly, and some rather more sandy. A few notably different stone types were seen, including a friable dark reddish brown sandstone, flint, quartzite river cobbles, and powdery soft mudstones of chalk or something similar.

The pinkish limestone fragments are likely to be indicative of exposure to heat (Fig. 4.38). The changing colour of stone on heating has been shown to be caused by the decomposition of certain iron minerals present in the stone, in this case most probably limonite, which decomposes at around 300 degrees and turns some limestones pink.[366] The heat could feasibly come from heating buildings using a hypocaust, or through the burning of the building by accident.

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[366] Chakrabarti *et al.* (1996) 539-40.

Figure 4. 38: Thin section macrograph of Sample 3842.1, a fine oolitic and shelly limestone with a relatively intense brownish pink colour, probably the result of heating to over 300 °C.

A great many fragments showed evidence of single nail holes. These were occasionally complete, but more often were observed in a broken edge, recognisable as a characteristic small curved notch, showing that the tile had broken through the hole, a clear point of weakness (Fig. 4.39).

Figure 4. 39: Large roof tile fragment from context 3807, with nail hole remnants in bottom right hand corner. Total length of incomplete fragment is 27 cm.

4.2.2.2. Lithologies

The results of the thin section analysis of the stone are limited to simple lithological descriptions, which are then compared with what is known about the local geology (Catalogue 1) in order to attempt to match the two together. Full description of the lithologies studied can be found in Catalogue 3, but these can broadly be divided into four categories: a very coarse dark red or brown greywacke, fine oomicrites, coarse shelly oobiosparites, and fine quartz arenites (Fig. 4.40).

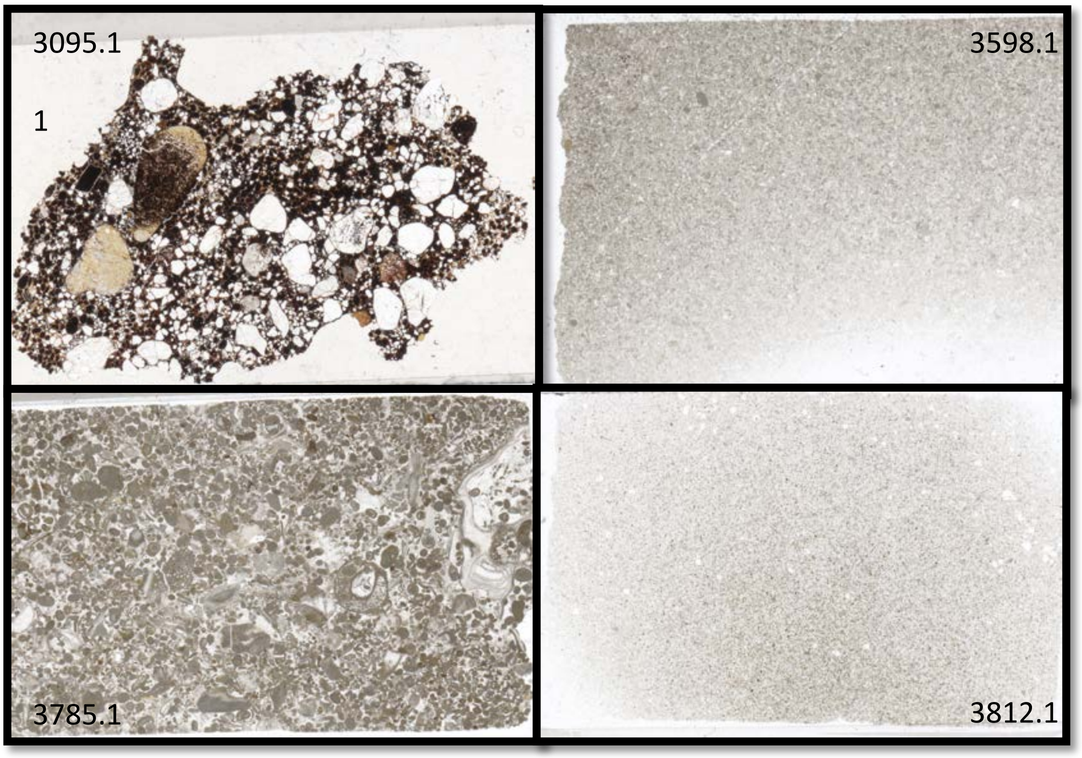

Figure 4. 40: Examples of the four main lithological types: (clockwise from top left) a coarse brown greywacke, a fine oobiomicrite, a fine quartz arenite, and a coarse oobiosparite.

Considering the geological deposits in the region, these lithological descriptions (and the additional hand specimen observations) allow the postulation of several source formations for the building stone in use at Dorchester on Thames. As noted above (Chapter 3.2.4), comparisons between archaeological stone descriptions and the published geological literature can be difficult to make, predominantly on account of the great variation within a single formation and the similarities possible between formations.[367] Thus, unfortunately, it is very difficult to definitively identify and provenance the limestones seen in the assemblage, given the range of comparable limestones outcropping in the region. Some of the more distinctive stones were confidently identified, but most simply have to be presented as having a range of possible source locations.

In hand specimen the presence of flint and chalk were plain, both originating in formations from the Chalk Group. Fine, greenish, soft powdery building stones, not thin sectioned, can be equated with the Upper Greensand Formation, whilst the brownish red very coarse greywacke (including sample 3095.1) can be equated with the Lower Greensand Formation (Fig. 4.41).

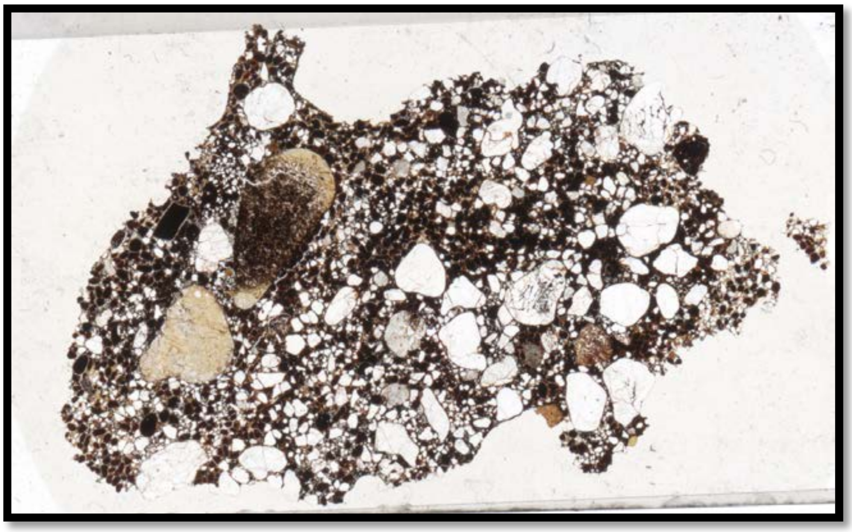

Figure 4. 41: Sample 3095.1 in thin section macrograph, a very coarse, poorly sorted, iron stained greywacke sandstone, equated with the Lower Greensand Formation.

The very shelly oobiosparites, including 3771.1, 3785.1, 3812.2, and 3842.2 can possibly be equated with the Forest Marble Formation, known for its highly bioclastic and oolitic

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[367] The author's thanks go to Philip Powell for his advice and assistance with trying to identify the stones in the assemblage.

facies, and indeed also for the existence of thin flaggy facies ideal for producing tile-stone (Fig. 4.42).[368]

Figure 4. 42: Sample 3812.2 in thin section macrograph, a coarse bioclastic and oolitic sparry limestone, possibly to be equated with the Forest Marble Formation.

Another moderately confident identification is that of Stonesfield Slate, or at least a very similar fine, grey, micaceous and sandy limestone which is readily split into thin tiles. Sample 3799.1 might tentatively be identified in this way (Fig. 4.43).

Figure 4. 43: Sample 3799.1 in thin section macrograph, a fine, slightly sandy and micaceous limestone, possibly to be equated with the Stonesfield Slate.

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[368] Horsfield (2013) 119. Powell agreed with this identification, although Maurice Tucker at the University of Bristol has questioned it: it is acknowledged that it is possible other formations in the region might also yield similar shelly, flaggy oobiosparites.

Finally there is the largest part of the assemblage, generally pale cream, yellow, or light grey oolitic limestones of varying degrees of fineness, generally micritic but with varying degrees of spar, and occasional shell fragments (e.g. Sample 3598.1, Fig. 4.40 above). This description could fit that of a number of stones, giving possible sources in the Portland Formation, or from Great Oolite Group limestones, including perhaps the Chipping Norton Limestone, the White Limestone Formation, the Taynton Limestone Formation, or the Cornbrash. All of these identifications will be discussed further in Chapter 5.5 and 6.2.

4.3. Evaluation of Approaches to Building Materials

It is worth a few brief key thoughts evaluating the methodology used here, and approaches to building materials more broadly.

4.3.1. Excavation Procedures and Recording

The survey of construction techniques and construction materials in Chapters 2 and 3 revealed the variation in the quality of excavation reports in their handling of these subjects. When site reports offered only limited descriptions, images, and interpretation of excavated buildings it became very difficult to make use of the information which was present. Precise dimensions and detailed drawings of *in situ* walls, material shapes and sizes (e.g. rubble block dimensions, and proportions of stone to mortar), and patterns of positioning are all crucial details. Evidence of less-permanent structures must be actively sought, including possible beam slots, post holes, or earth walls, and careful soil archaeology is therefore necessary for identifying these often subtle features. In addition, disaggregated building materials in the surroundings of a building should be carefully surveyed and described in relation to the structure.

Full excavated material retention is not always feasible because of archiving pressures. However, if excavation logistics do prohibit complete retention, then at least the full assemblage needs to be surveyed prior to redeposition. Morphological aspects need to be fully described, including complete dimensions, and, crucially, substantial fabric samples need to be collected, representative of the whole assemblage, not biased towards particular types of material.

One of the key difficulties highlighted in this work is the uncertainty and variation which makes linking archaeological material with raw geological materials problematic. More light needs to be shone onto raw material extraction and production sites, things which will be discussed further below (Chapter 5): these need to be sought more frequently, and need to be more comprehensively recorded when they are discovered. Kiln wasters, quarry wastes, and, if possible, raw materials in the vicinity ideally need to be comprehensively sampled, in order to provide the material baseline against which more data can be compared.

4.3.2. Analytical Approaches

This brings us on to the question of analytical methodology. The techniques used here worked well, particularly for investigating the production processes of CBM. A more precise chemical technique, such as powder XRF, might have been used to further characterise samples, although until we have a comprehensive material baseline, larger datasets, and a greater understanding of the chemical variation possible in both raw materials and finished products, this will be of limited use. Similarly, SEM and ICP-MS might be used for adding further characterisation to the stones, with microtextural, chemical, and isotopic information, but again until those material baselines are in place this would be of limited use.

Fundamentally then, in order to maximise our understanding of Roman building material and so facilitate the full potential of scientific analyses of these artefacts, the publication by researchers of their databases, in a format that makes them useful for comparison, is critical. With the increasing power of chemical characterisation techniques, now essential are the development of standardised methodologies and calibration standards to allow large datasets to be compiled facilitating comparison.

5. Building Material Production

"All lands do not possess similar qualities; nor is stone universally found." – Vitruvius, *De Architectura* II.6.5.

In this and the following chapter we return to examining the chaînes opératoires of ceramic and stone building materials, giving heightened detail on the basic schemes given in Chapter 3, and proposing specific conclusions with regard to the operation of these productive activities in Roman Oxfordshire given the insight gained through the work of Chapter 4. This chapter considers the first stages of the chaînes opératoires, with discussion of the possible sources of raw materials, and the location and nature of production, including brief discussion of the methods, processes, tools, and labour involved. This high-resolution focus on building materials is unusual but powerful, and it is hoped provides a model for future work on sites of all periods.

There are two main routes utilised here for exploring this: examining physical archaeological evidence for sites of raw material extraction, and examining the material itself as found on its site of use and deposition. We will begin with the former, before moving on to the latter.

5.1. Archaeological Evidence for Sites of Building Material Production

No sites of Roman extraction or production of building material have been excavated in Oxfordshire, and just one CBM kiln has been identified based on tile wasters identified in field-walking.[369] Undoubtedly there must have been many building material production sites in the region in the Roman period, feeding the demand at the town sites of Alchester and Dorchester, as well as at the numerous roadside and rural settlements, farmsteads,

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[369] Speake (2012) 76.

and villas. Thus the study of building material production is difficult: the limited archaeological evidence that we have for sites of ordinary Roman building material acquisition and production in the wider region only represents a very small proportion of what once existed. This stems from a combination of a lack of study, combined with the difficulty of identifying such sites. Difficulties dating extraction sites adds a further obstacle to our task. These issues will be discussed below.

5.1.1. Finding Sites of Extraction and Production

A number of factors contribute to our difficulties discovering sites of Roman building material extraction and production. This is not to say that nothing is known at all, and Pearson's 2006 work on stone use and quarrying in Roman Britain, together with Russell's 2013 work on the economics of the Roman stone trade, synthesize a great deal of evidence, and present a positive outlook on our constantly growing understanding of the subject of building stone extraction in particular.[370]

There exists a question of where we should be looking for such sites. These are materials which, as demonstrated in Chapter 2.5, are heavy, are needed in large quantities, and are thus difficult and expensive to transport any great distances, an issue discussed further in Chapter 6. A generalised economic argument would therefore suggest that production sites should be as close as possible to the site of use: the less far one has to transport a heavy or bulky good, the cheaper it would be. This certainly holds true in some cases: at Cirencester, for example, shallow pits, interpreted as small scale stone workings, have been identified directly outside of the town walls.[371]

However, extraction and processing sites for stone and ceramic building material production have not been studied regularly or thoroughly enough to test this hypothesis

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[370] Pearson (2006); Russell (2013a).

[371] Pearson (2006) 56.

satisfactorily, and indeed there is growing discussion of the suggestion that, even at relatively minor sites, building materials were not necessarily extracted from the direct vicinity.[372] We can create some distribution maps, for example of known CBM kilns in Roman Britain (Figs. 5.16 - 5.20, below), and the relationship of these to Roman towns, amongst other natural and human landscape features, is investigated below. It remains true that our data are patchy, with tile kiln sites and stone quarries having been relatively poorly investigated.

Indeed two broad factors actually argue against this hypothesis of purely local production of building materials. Firstly, the materials sought are not ubiquitous: satisfactory quality building stones available in accessible outcrops, or clay that suits the tile-makers' needs, do not occur evenly across landscapes, as recognised by Vitruvius, quoted at the start of this chapter, and as shown on a basic level by the distribution of historical quarries in Fig. 5.11 and 5.12 below.[373] Proximity to a particular natural resource might only in exceptional circumstances factor highly in the choice of a settlement location (a scenario most obviously demonstrated by the imperially controlled and developed mines and quarries, set distinctly in their own operational territories, as elucidated by the Vipasca tablets).[374] The majority of extractive sites would most likely have been in agricultural territories controlled privately or municipally. When good quality clay or stone could not be found in the direct vicinity of a town, these will have needed to be acquired from wherever they were of a quality and had the accessibility to be utilised.

Secondly, it stands to reason that the rather destructive activity of digging pits and quarries for clay and stone, or the management of significant areas of woodland for fuel for kilns, cannot occur on a large scale immediately within urban areas. These activities

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[372] As at the recent "Building Roman Britain" conference, Bath, 10.11.17.
[373] Vitruvius *De Arch.* II.6.5.
[374] Hirt (2010) 49.

also disrupt farming, taking up space which might otherwise be used for arable fields. It might be suggested, therefore, that they are thus likely to have been situated in what were relatively rural areas in the Roman period, away from the urban cores and their immediate, productive, hinterlands. Young discusses this phenomenon in his considerations of the location of the Oxfordshire pottery industry, sited away from major urban centres, despite the obvious economic advantages to the industry of having a local work force and market.[375]

We might expect, if building material extraction sites were located in the direct vicinity of towns, that more would have been found. Holbrook and Morton showed in their survey of Romano-British site "grey literature" that, in the direct vicinity of Roman "civil settlement" cores, much more commercial excavation has taken place, whilst the further you get from those cores, the fewer modern archaeological investigations that have identified Roman remains there are.[376] Within a radius of 0.5 km of the 156 *coloniae, civitas capitals*, spas, and small towns collectively referred to as "civil settlement" in the AMIE database, the AIP records an average of 10 investigations per square kilometre, falling to 4 per square kilometre in a 0.5 - 1 km radius, and 0.1 per square kilometre within a 1 - 10 km radius.[377] As the authors of that study note, this probably predominantly reflects the fact that many modern towns lie on top of the fossilised remains of Roman towns, and it is in these modern towns that most redevelopment, and therefore archaeological work, is being done.[378] Whilst this could stem from the difficulties of recognising extractive sites, on account of a lack of understanding of their morphological characteristics, this surely predominantly reflects the fact that extraction and production sites are not in fact located

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[375] Young (1977) 12-13.

[376] Holbrook and Morton (2008) 34; Fig. 12.

[377] Holbrook and Morton (2008) Fig. 12.

[378] Holbrook and Morton (2008) 34.

close to urban cores, where they would have been found, but are sited in those radii where far lower levels of intervention have been carried out.

Across the Empire quarries are most easily identified when they are large and when they are situated in landscapes which have not seen a high intensity of post-Roman development which might destroy or conceal the Roman evidence. Examples of this include the huge imperially run quarries in the Eastern Desert in Egypt, such as that at Mons Claudianus, or the Numidian marble quarries at Chemtou in Tunisia. Aerial photographs of these sites very clearly show the remains of stone extraction, both through visible scars in the landscape as relics of the quarrying activity as well as standing remains of Roman buildings associated with the enterprise (Fig. 5.1).

Figure 5. 1: Numidian marble quarry scars and stone workshops at Chemtou, Tunisia. (Google Earth, © 2017 DigitalGlobe.)

Aerial or field survey stand as powerful tools for identifying extractive sites, but obviously these techniques only work as long as sites remain visible at the surface. In the above examples a number of factors seem likely to preserve the ancient workings and maintain their visibility across such a long period of time. Firstly, these are large quarries from which exceptionally large volumes of stone were extracted, and are thus easier to identify and more likely to survive, at least in part, and thus our dataset will be biased towards extraction at this larger end of the scale. Secondly, relatively low levels of post-Roman activity, settlement, and development in these regions have led to greater visibility. In such landscapes Roman extractive sites are less likely to see continued exploitation in later periods, which destroys the traces of Roman working. Abandoned Roman quarries which have not been intensively worked in later periods will be identifiable by unfinished pieces (e.g. columns only half-extracted or not transported further, as at Mons Claudianus), quarry waste, including failed pieces (e.g. the *ravaneti* of the Carrara Quarries in northern Tuscany), and identifiably Roman quarry markings and graffiti, (e.g. as at Gelt Quarry in Cumbria, where tool markings are preserved together with several inscriptions which name individuals, units, and the legions responsible for working at the quarry, and even the consuls of the years that they were there).[379] Besides a continuity of extraction, more densely settled landscapes might also cause extractive sites to become filled in: disused quarries or pits provide excellent locations for the discarding of waste, and landscapes with higher densities of human occupation might be more intensively farmed, which, as discussed below, further increases the chance of extractive sites (especially smaller ones) being hidden from surface surveys.

Thirdly, the North African climate of the Egyptian and Tunisian examples above impacts how visible Roman quarries or extractive pits might be in a survey. The hot, arid climate tends to reduce the density of vegetation growth, which therefore does not conceal out-of-use quarries from aerial or field survey. A further consequence of this is that soils form

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[379] Mons Claudianus: Hirt (2010) 15; Carrara: Dolci (1985), (2003); Gelt Quarry: Collingwood and Wright (1965); Davies (1968).

at a much slower rate than in temperate regions, and topsoil is more easily washed or blown away without vegetation to secure it. [380] (Although conversely, wind-blown sands or soils might on occasion fill and conceal extractive pits in this climate.) In more arid regions farming tends to have been practised at lower intensities than in temperate regions, on account of the thin soils and low rainfall. Arable farming, and the highly destructive component activity, ploughing, might aid in the concealment or destruction of disused pits, and so more intensively farmed landscapes might make aerial and field survey less likely to discover ancient sites, including extractive pits.

We would expect Roman extractive sites to be much more difficult to identify in Britain, and in Oxfordshire in particular, on account of high levels of human activity in the intervening centuries, including quarrying and farming, compared to sites in the Eastern Desert of Egypt. By the close of the 18th century, historical maps show that c. 71.8 % of Oxfordshire was in use as agricultural land.[381] Many of the stone sources of Oxfordshire have been exploited on a significant scale in the medieval and post medieval periods, for development of villages and manor houses, construction in Oxford, and higher quality stone was often exported beyond the county boundaries, to London for example after the Great Fire of 1666.[382] This has led to the high possibility that any Roman workings may have been destroyed by subsequent quarrying. Similarly, Oxfordshire has historically been a significant brick and tile producing county, with works including those at Nettlebed, Wolvercote, Chawley, and Wheatley: it is possible that these may have removed traces of Roman clay extraction.[383] The temperate, wet climate, and landscape characterised by lowland and gentle hills, permits rapid plant succession and accompanying high rates of soil formation, which conceal and fill disused pits. References can be found in the Victoria

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[380] Gennadiyev and Chernyanskii (2006) 291 ff.

[381] Tompkins and Malone (2017).

[382] Mobus (2015) 273.

[383] *BritPits* database: *cf.* Fig. 5.15, below; Crossley and Elrington (1990) 242.

County Histories to the in-filling of disused quarries with refuse, such as the Boddington Lane Limepit, North Leigh.[384] In sum, extractive sites are difficult to recognise, and thus careful attention needs to be paid during excavation for signs of past building material extraction.

5.1.2. Dating Extractive Sites: The "Longue Durée" of Extraction

A key issue which we face if and when we do identify extractive sites is a problem dating the period or periods of use. Quarries yielding high quality building stone in an advantageous location, for example near to a major town, are very likely to have seen multiple phases of exploitation, particularly if that Roman town continued as a centre for settlement into later periods, as is often the case in Britain. Securely dating extractive sites as having been exploited in the Roman period might be possible through two main routes: the recovery of Roman finds from within the extractive site (although this usually requires the relatively expensive process of excavation) or through the identification of characteristically Roman tooling marks or waste patterns on an exposed quarry face.

For example, at the Carrara quarries in Tuscany, Roman stone waste can be distinguished from more modern waste on account of the dominant size and shape fractions within the waste heaps, or *ravaneti*.[385] Large irregular clasts around 50 cm in size, held in a fine silty and sandy matrix, and with little weathering or patina, are indicative of modern quarrying techniques utilising explosives and mechanical saws; so-called "testa d'uomo" *ravaneti*, consisting of cobbles between 10 and 30 cm in diameter and supported in a sandy matrix attest to 19th-century practice of sorting waste by size for use in dry-stone walling, the "teste" being the rejected pieces; and underlying buried soils are *ravaneti* consisting of "flat pebbles with an open-work structure," indicative of Roman quarrying at the site.[386]

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[384] Crossley and Elrington (1990) 224-230.

[385] Baroni *et al.* (2010).

[386] Baroni *et al.* (2010) 239-40. The meaning of "open-work structure" is unfortunately rather unclear.

Unfinished marble blocks, columns, and capitals, as well as remains of iron tools, are fairly common finds from excavation of Roman layers at several sites in the Carrara area, although pottery is noted as being scarce, making more precise dating difficult.[387]

It is frequently suggested that tool marks may enable the identification of Roman as opposed to later, or indeed earlier, extraction and working of stone, and the work of Blagg and Bessac offers a great deal by way of guidance for recognising particular types of marks and understanding what type of tool made them and for what purpose.[388] The recent *Art of Making in Antiquity: Stoneworking in the Roman World* project at Kings College London explored in detail the marks left on Roman carved stone through analysis of working practices.[389] Suggestions can be made through close analysis that particular marks indicate expressly Roman, rather than later, tooling, but often tools, techniques, and working practices were very similar in medieval stone extraction and carving, ensuring that caution must be taken when relying solely on this evidence for dating an extractive site.

Despite these difficulties, the high intensity of study of the British landscape furnishes several opportunities for attempting to discover ancient extractive sites. In consideration of building material production we will firstly be discussing quarries for stone; we will then briefly consider the much more difficult to identify extraction sites for earth for construction, and then pits for clay for brick- and tile-making, before moving on to discuss the subsequent steps of their production.

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[387] Baroni *et al.* (2010) 240.

[388] Blagg (1976); Bessac (1986); Peacock (2013) 23-24.

[389] Wootton, Bradley, and Russell (2013). URL = http://www.artofmaking.ac.uk/ (Accessed 14/11/17).

5.2. Building Stone Extraction and Production in Oxfordshire

Whilst no definite examples of Roman quarry sites have been discovered in Oxfordshire, and despite the problems noted above posed by continuity in building material production, this continuity also offers an opportunity. Consideration of quarrying from all periods prior to the modern in a localised study may give us a greater understanding of the Roman situation, under the assumption that analysis of all pre-mechanised periods might reveal consistency of approach, and consequently insight into periods for which we have less evidence, such as the Roman. Thus an exploration of where quarries have been situated in Oxfordshire in the medieval and post-medieval periods, giving an understanding of the particular stones which were valued and the particular parts of the landscape from which they were extracted, and then used, may assist us in our understanding of the production and supply of building materials in the Roman period. Three main approaches are used here: surveys of building stones used for medieval buildings in Oxfordshire (better studied and synthesised than Roman period use, on account of many buildings still standing from these periods, with associated surviving written records); a survey of historical quarries, as listed in the BGS *BritPits* database and the BGS and Historic England *Strategic Stone Study* database; and a terrain- and map-based landscape approach used to explore in greater detail the physical settings of quarries.

5.2.1. Stone Use in Medieval and Post-Medieval Buildings around the County

Useful surveys of building stones exploited in the medieval period in Oxfordshire have already been undertaken, firstly by Arkell in his 1947 work *Oxford Stone*; secondly by Martyn Jope, focusing on early medieval building stone use in southern and midland England; and most recently by Horsfield *et al.*, who discuss building stone choice for domestic architecture across the county from the last four centuries.[390] Jope's conclusions note in particular the importance of Jurassic oolitic limestones for ashlar and freestone used in Saxon churches, which "largely repeats a pattern developed in Roman Britain;" unfortunately Jope does not elaborate on or reference this statement, and whilst he does write a brief footnote acknowledging that "blocks of freestone in Saxon work may of course occasionally have been reused material from Roman work," this seems to seriously underplay the significant role of spoliated Roman material in post-Roman construction.[391] The conclusions from Horsfield *et al.* note that, generally, building materials commonly used in the construction of villages across Oxfordshire are from the stone sources most locally available: a not unexpected conclusion, and one which, to some extent, will apply to Roman period construction as well.[392] The application of the term 'vernacular' to such buildings, often dwellings or commercial or productive premises, is in part determined by their use of local building materials, and in Chapter 7.4 the question of whether the term might be useful in our understanding of Roman construction will be addressed.

Horsfield *et al.* do note exceptions to this general rule of local material use: the first is in roofing material, in particular noting the perceived importance of Stonesfield Slate for this purpose across the vernacular architecture of Cotswold villages, even those at some considerable distance from the source.[393] The second exception is in the "critical components such as quoins or lintels where strength was essential," when better quality materials were employed if local stones were not strong enough, or could not be quarried or worked into suitable sizes and shapes of block.[394] Finally, the most obvious exception lies in more prestigious, and perhaps more 'architectural' (as opposed to vernacular), constructions, where a far greater diversity of building materials is seen beyond the local.

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[390] Arkell (1947b); Jope (1964); Horsfield *et al.* (2013).
[391] Jope (1964) 91; *cf.* Eaton (2000).
[392] Horsfield *et al.* (2013) 123; *cf.* Pearson (2006) 11.
[393] Horsfield *et al.* (2013) 126.
[394] Horsfield *et al.* (2013) 123.

Good examples of this are provided by manors, other higher class residences in the county, and Oxford colleges, whose buildings frequently make use of diverse and distant stone sources instead of relying solely on the much more locally available Headington stones quarried a few kilometres south east of the city.[395] Examples of this include both architectural ornamentation as well as the fundamental construction stone of buildings, for instance the Forest Marble Formation stone used for the columns in the cloisters of Canterbury Quadrangle, St John's College, dating to the early 17th century; the Marlstone Formation stone used in the Meadow Building, Christ Church College, dating to the 1860s, and the Taynton Formation stone, first known to have been used in Oxford in the 13th century to face Mob Quadrangle at Merton College.[396] As noted, various manors and country houses in the county make use of non-local stones for fine freestone ashlars, for example Blenheim Palace exploiting a deep quarry at Cornbury Park to access Clypeus Grit Formation stone.[397]

5.2.2. Stone Use in Dorchester

Looking particularly at the building materials used in medieval and post-medieval Dorchester, stone is comparatively rare, used only in a few of the older buildings in the village, with a predominance of brick walling in buildings, together with the occasional earth wall on property boundaries. This reflects that fact that there is no particularly high quality building stone in the vicinity of the village, which sits on the Gault Clay. The major stone-walled buildings include the Abbey, by far the most significant use of stone in the village, but it is also used in the walls of the hall at the rear of the George Inn, and in houses on High Street, Rotten Row, Bridge End Street, and Queen Street. Only in the Abbey and a house on Queen Street is stone seen used for quoins, lintels, and window frames; around

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[395] Arkell (1947b) 24, 34, Fig. 1 and 4.

[396] Horsfield *et al.* (2011).

[397] Arkell (1948).

the rest of the village these features are most often seen faced in brick. Some property boundaries are built from stone rubble. Not a single stone roof has been seen in the village by the author, all made from ceramic roof tiles or thatch.

The Abbey itself makes use of significant quantities of both a paler and a darker yellow fine oolitic and slightly shelly freestone, used for the quoins, window sills, casings, and mullions, and architectural ornament, as well as occasionally as ashlar dimension stone (Fig. 5.2). This stone is occasionally also seen used in other buildings in the village, with a particularly similar group of ashlars in the back wall of the George Inn hall. It is possible that these originate from the Great Oolite, imported from the north of the county, perhaps coming from the Cornbrash, White Limestone, or Taynton Stone Formations; this author certainly has not seen such fine freestone used in the vicinity of the Portland Formation outcrop, nor are such large, fine, durable ashlars particularly characteristic of the Wheatley Limestone outcrop at Headington.[398]

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[398] Although Rodwell does suggest an origin in the Wheatley Limestone from Headington (2009).

Figure 5. 2: Fine oolitic freestones used in the Dorchester Abbey. Scale bar: 1 m, lens cap: c. 70 mm.

The stone coursing of the Abbey walls show some variation in building materials and techniques, displaying multiple phases of construction and alteration (Fig. 5.3 L). A commonly seen stone is a slightly friable mid orangey yellow limestone. It is thought that this might be quarried from the Portland outcrops north east of the village, in the vicinity of Little Milton or Great Haseley, where a very similar looking stone has been observed (Fig. 5.4). A number of other limestones are seen used in the Abbey and around the village, including a white or pinkish white, very hard, sparry limestone with frequent large oyster shell intraclasts (Fig. 5.5). Analogous materials could not be found on the Portland outcrop, and so the Wheatley Limestone or Great Oolite seem more likely sources.

Figure 5. 3: Different types and shapes of limestone used in the Abbey walls and in a property wall on Bridge End Street, Dorchester on Thames.

Figure 5. 4: A pale yellow, friable micritic limestone, photographed in the walls of Dorchester Abbey (top), in Little Milton, and in Great Haseley (bottom). Lens cap: c. 70 mm.

Figure 5. 5: Hard sparry pinkish white limestone with oyster shells, in the Abbey walls (top), in a house on Rotten Row (bottom left and in the George Inn (bottom right), Dorchester on Thames.

Around the village, including in the Abbey yard boundary wall, in the front boundary wall of St Birinus Church, and in a number of houses in the village, a much softer, finer, pale greenish white sand- or siltstone is seen, originating in the Upper Greensand, probably quarried somewhere to the south east of the village (Fig. 5.6). Other villages in the vicinity making use of this stone include Warborough, just 2 km to the south east.

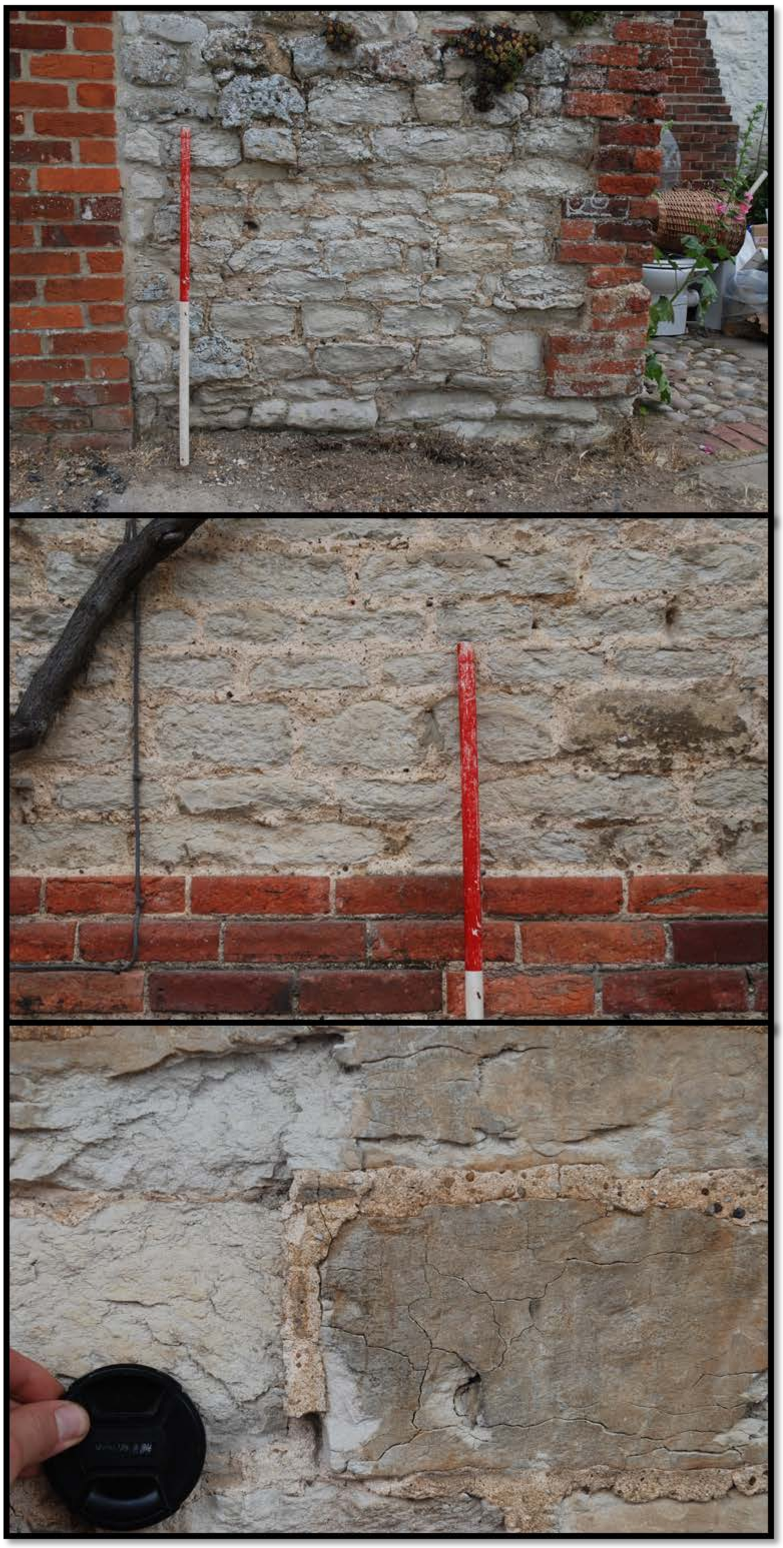

Figure 5. 6: Upper Greensand stone used in houses on Bridge End, Rotten Row, and Queen Street, all in Dorchester on Thames. Scale bar: 1 m (or 0.5 m); lens cap: c. 70 mm.

Flint is occasionally used in the village, either as rough nodules, used to repair the Abbey walls, or in two houses as ornamental panels (Fig. 5.7 top). A coarse, red, sandstone is also occasionally used, again for repairs to the Abbey walls, probably quarried from the Lower Greensand outcropping north of the village between Burcot and Culham (Fig. 5.7 bottom).

Figure 5. 7: Flint used to make decorative panels in a brick-faced house on Bridge End, and Lower Greensand used in the Abbey walls, Dorchester on Thames.

Earth walls, seemingly cob, can be seen in the garden walls at the back of the Fleur de Lys pub, and the front wall of a property on the High Street; the earth is a dark orangey red, suggestive of its origin being in the loess deposit which overlies the river terrace gravels in the village (Fig. 5.8). The cob walls are set on a stone rubble foundation (Upper Greensand) c. 70 cm high, and are topped with thatch.

Figure 5. 8: Cob wall, based on Upper Greensand footing, at the Fleur de Lys pub, Dorchester on Thames.

The presence of stone-walled buildings, but absence of stone-roofed, in the village is interesting and poses a problem: the Roman assemblage presents the very opposite, being largely barren of walling stone and dominated by stone roofing material. The Upper Greensand is certainly too soft for use as tile-stone, despite its occurrence in relatively thin facies, and one assumes that the Portland limestone must not occur in suitably flaggy facies which can be split easily into thin tile-stones, since even in the villages which lie directly on top of the outcrop the only roofing materials seen are ceramic and thatch. The highly variable construction materials seen across the village lend themselves well to a tentative hypothesis that some proportion of the stone is reused, and may well be spoliated from Roman stone buildings, whilst it might also be tentatively suggested that the Roman builders in the town brought stone from further away, particularly roofing material.

5.2.3. Historical Quarries in Oxfordshire

A primary approach to identifying the locations of historical quarries is to investigate placename evidence. There is one particularly early and useful placename in the county of interest to this project: Standhill, a hamlet in the parish of Pyrton, Oxfordshire, apparently furnishes one of the earliest dependable placenames referring to quarrying in the whole country (Fig. 5.9).[399] Attested in a charter boundary of AD 1002 in Old English as *Stangedelf*, meaning stone quarry, and referring to a place situated on the very edge of the outcrop of the Portland Group at its interface with the Gault Group, this early place name gives very strong evidence of quarrying in the early medieval period, and possibly even earlier. This site is actually one of the very closest outcrops of limestone to the Roman town at Dorchester on Thames, and thus offers significant potential as a site for acquisition of building stone for the town.

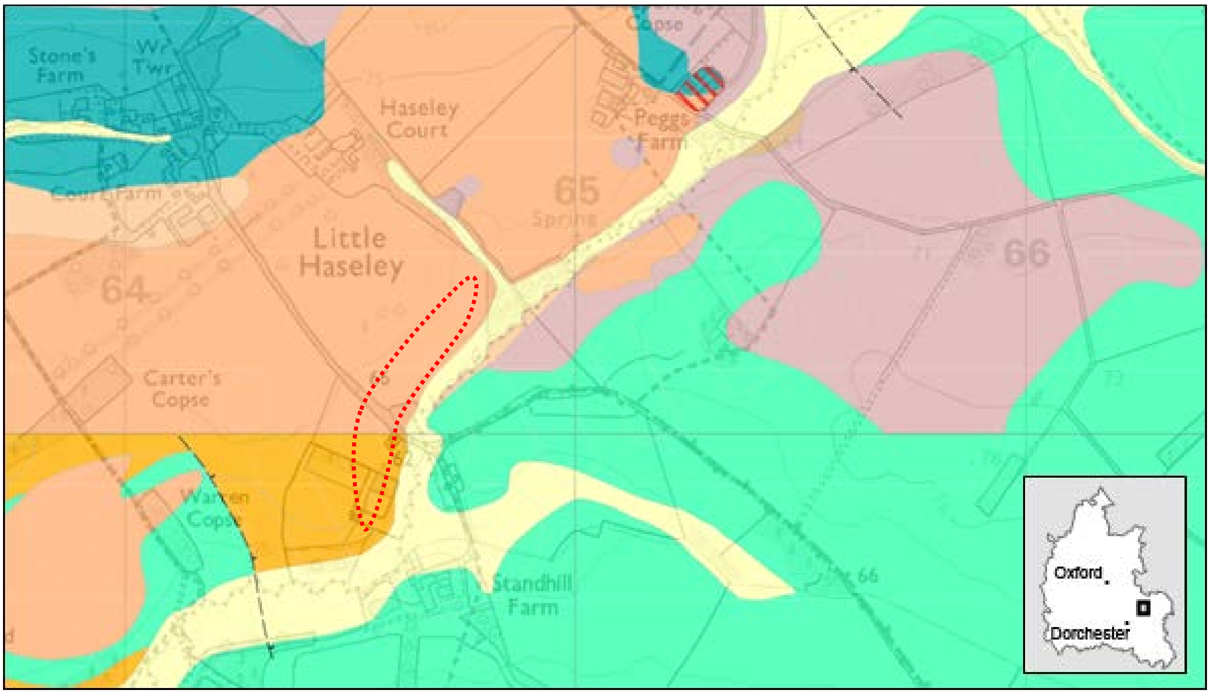

Figure 5. 9: The probable location of the Standhill Portland Limestone Quarry (dotted red line) referenced in its placename, at the edge of the Portland Group outcrop (orange-red) overlain by the Gault Clay (light green). Grid squares are 1 km. Geological Map Data © NERC 2017. Crown Copyright and Database Right 2017. Ordnance Survey (Digimap Licence)

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[399] Parsons (1991) 7.

Arkell's survey of stones used in the buildings of Oxford, published in 1947, provides the most detailed survey of historical quarries in the county, Arkell having been able to consult the folk knowledge of still-living quarrymen, as well as including surveys of Oxford college building records.[400] Robert Plot's *Natural History of Oxfordshire*, published in 1677, forms another excellent source for the origins of the stone in several important buildings, as well as the operation of quarries in his time.[401] Beyond these, one other key means of identifying historical quarries is through catalogued records from more recent history. The *BritPits* database, curated by the British Geological Survey, holds information on currently active but also inactive and closed workings, recording, where known, the operator, the location, and the lithology being worked. This database includes many historical sites including all of the disused "pits" and "quarries" marked on OS 1:25,000 maps, and comes to 2631 sites in Oxfordshire (Fig. 5.10).

A further source is the BGS and Historic England *Strategic Stone Study* database. This dataset was collected in a national study which surveyed stone use in regionally representative samples of structures such as historic buildings, boundary walls, bridges, and paving, and was run county by county from 2004. The purpose of that study was to identify the most significant stones, and where possible the original quarries for these stones, for the purposes of aiding repair and restoration, and to provide local authorities with guidelines for material use in order to maintain local character in new constructions. The dataset for Oxfordshire, completed in 2011 by Bill Horsfield, includes data on 151 buildings from around the county, 107 quarries, and 45 stone types (Fig. 5.11).[402]

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[400] Arkell (1947b); (1948).

[401] Plot (1677)

[402] Horsfield (2011) and URL = http://www.bgs.ac.uk/mineralsuk/buildingStones/StrategicStoneStudy/EH_atlases.html (Accessed 22/11/2017).

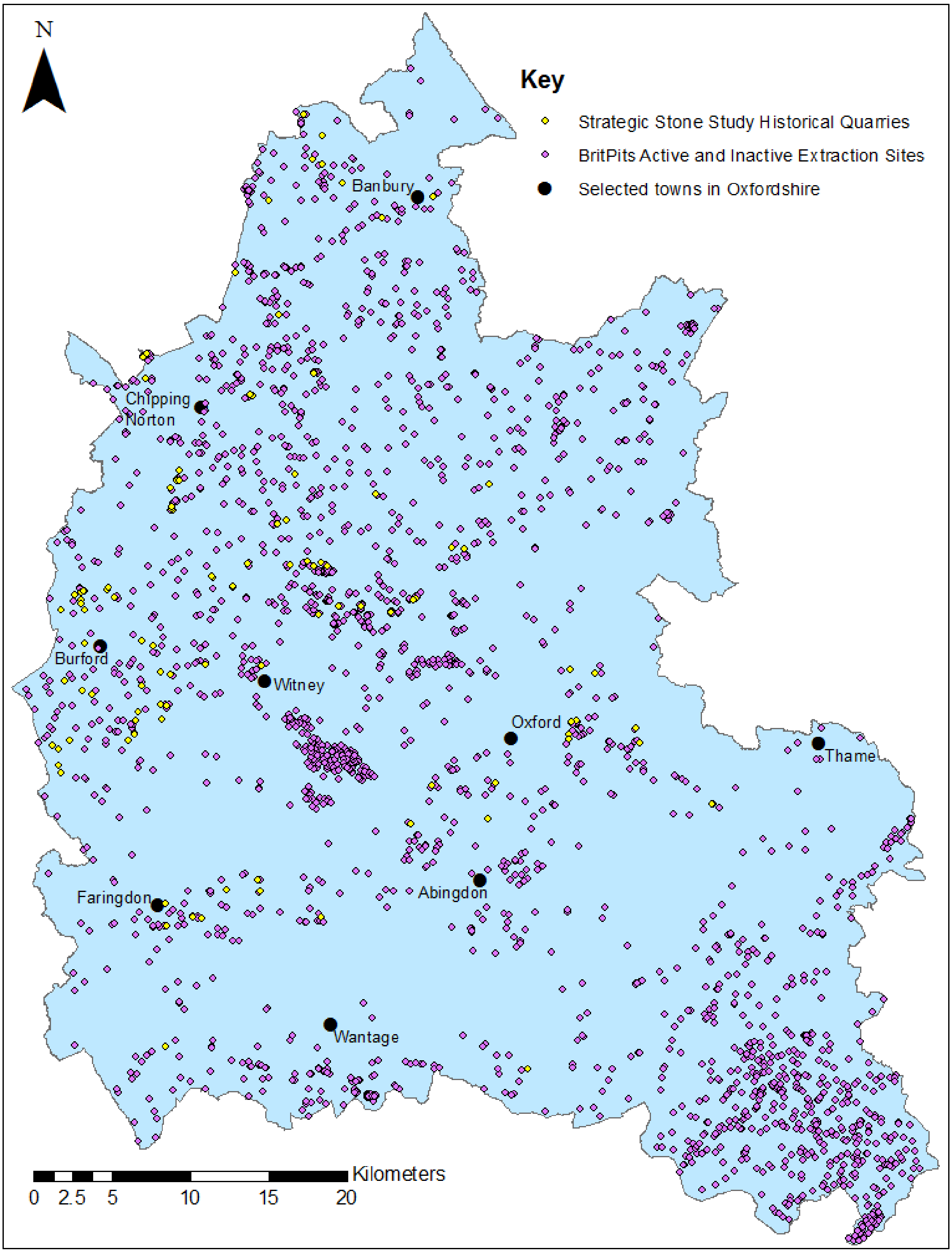

Figure 5. 10: Map showing all known historical and currently active quarries in the county of Oxfordshire, listed in the BritPits Database and in the Strategic Stone Study Database. Quarry data © NERC 2017.

These two datasets have been used here together to investigate important lithologies exploited for building stone in the county in the present and recent past. Before discussing what this shows, it is important to note that these databases do have limitations: neither database, despite having field-headings for dates of use, contains any information for periods of quarry use in Oxfordshire, beyond noting whether it is currently active or not. Nor does either dataset contain any significant bibliographic details.

Significant extractive activity, particularly in the modern period, and particularly of limestone, is undertaken not for the acquisition of building stone but for other purposes such as aggregate, roadstone, agricultural lime, and cement manufacture. In historical periods stone quarrying for lime mortar production would also have taken place, but on a much smaller scale than the modern cement industry. The BGS kindly supplied further data, giving details of the end use of material extracted from the listed sites: of the 2631 sites listed in Oxfordshire, 1279 of them (49 %) unfortunately had this detail unspecified, but 163 had their end use described as one of "building stone," "decorative stone," "dimension stone," "flagstone," "roofing flags," "roofing slate," or "walling stone." The *Strategic Stone Study* database can be seen as a subset of the *BritPits* database, as it does not contain any quarries which are not listed in the latter, but offers the added value of the work of its authors in investigating and confirming the use of these 107 quarries for building stone production, and thus stronger conclusions can be made from this dataset on this account.

An additional issue to consider is the fact that the mapped bedrock of the 1:625,000 and 1:50,000 BGS geology maps only represents the uppermost rock formation; quarries have depth, and so determining the product of a quarry based on these maps might be problematic. The uppermost stone does not necessarily indicate the only, or even primary stone formation quarried from a pit, as seen in Arkell's discussion of the stones used at Blenheim Palace and Cornbury Park: the quarry within the grounds of the latter, known as Buckleap or Kennels quarry, was used not just to extract the surface bedrock of Taynton Stone, but also Sharps Hill Beds and Chipping Norton Limestone beneath it, and underlying this, apparently, a layer of Clypeus Grit (in the Inferior Oolite Group) which proved excellent for freestone, c. 20 m beneath the surface.[403] Thus we must always consider that quarries frequently work down through the highest level bedrock shown on geological maps (which may only be a metre or two thick) and might expose layers of underlying formations for use. Presumably, with relatively rich stone sources still available to them, Romano-British quarrying is likely to have confined itself to the far more easily discovered and extracted stone near the surface; we will talk more below about the possible processes of survey and exploration for stone (Chapter 5.2.4.2).

Bearing these caveats in mind, the locations and concentrations of quarries, exploiting particular rock formations, presumably largely reflects the most highly prized stone types. The factors influencing such concentrations can be investigated, ranging from a basis of physical characteristics, through to questions of ease of extraction, or ease of transfer to building sites and use. The situation of quarries can be compared with other landscape factors such as topographical setting, or proximity to rivers, roads, and settlements. The factors identified as being important for medieval and post-medieval quarrying can then be considered for their potential influences on Roman quarrying in the same region.

A map of the locations of the 163 Oxfordshire building stone quarries identified in the *BritPits* database overlaid on the geology of the county shows the exploitation of three broad geological zones of the county: the Marlstone outcropping near Banbury in the Lias Group deposits to the north of the county, the oolitic limestones in the band of Great Oolite Group stones along the Cotswold hills' southern slope, roughly from Woodstock to Carterton, and the Corallian and Portland Group limestones and sandstones outcropping in the central hills of the county, exploited predominantly around Wheatley, but also in the band of high ground stretching from Boar's Hill southwest to Faringdon (Fig. 5.11). The Great Oolite Group stones of the southern flank of the Cotswolds dominate the dataset,

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[403] Arkell (1948) 52.

with 109 of the 163 building stone quarries of the county. These exploit in particular the Stonesfield Slate at Stonesfield and Taynton Stone at Taynton and Burford, alongside widely spread exploitation of the Forest Marble Formation, the White Limestone Formation, the Cornbrash Formation, and the Chipping Norton Formation. The Marlstone quarries to the north comprise 30 of the 169 quarries in the county, and the stones of the central Oxfordshire ridge, including the Corallian Group Stanford and Kingston Formation limestones and sandstones, and the Portland Group limestones and sandstones, make up 22 of the 163 quarries. There is one quarry listed as exploiting the chalk deposits of the county, in the south west at Woolstone.[404]

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[404] *Cf.* Horsfield *et al.* (2013) Fig. 2 for the narrow distributions of use of chalk stone and chalk clunch, in the south eastern and south western corners of the county respectively, presumably reflecting particularly good deposits, perhaps also tied in with local traditions or an economic impetus in the local area to use these stones.

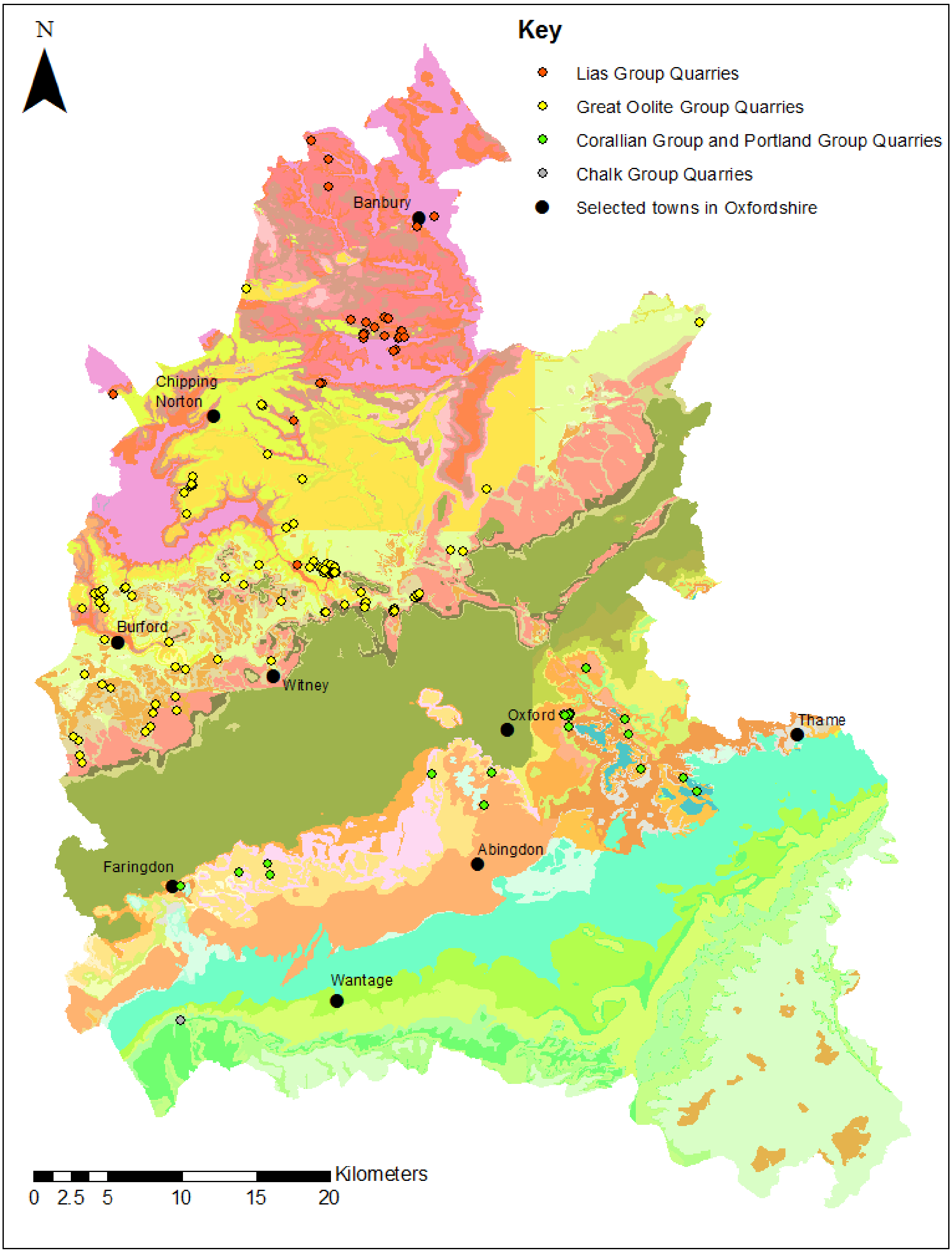

Figure 5. 11: Map showing quarries listed in the BritPits database known to have yielded building stone, coloured by outcrop group. © NERC 2017.

The slightly smaller *Strategic Stone Study* database (108 entries) shows much the same pattern, if not quite the same numbers, with 69 of the 108 quarries dug into outcropping rocks of the Great Oolite Group, 26 dug into the Corallian and Portland outcrop through the middle of the county, 11 in the Lias Group Marlstones in the north of the county, and a final two quarries for chalk building stone identified in the south of the county in the North Wessex Downs (Fig. 5.12).

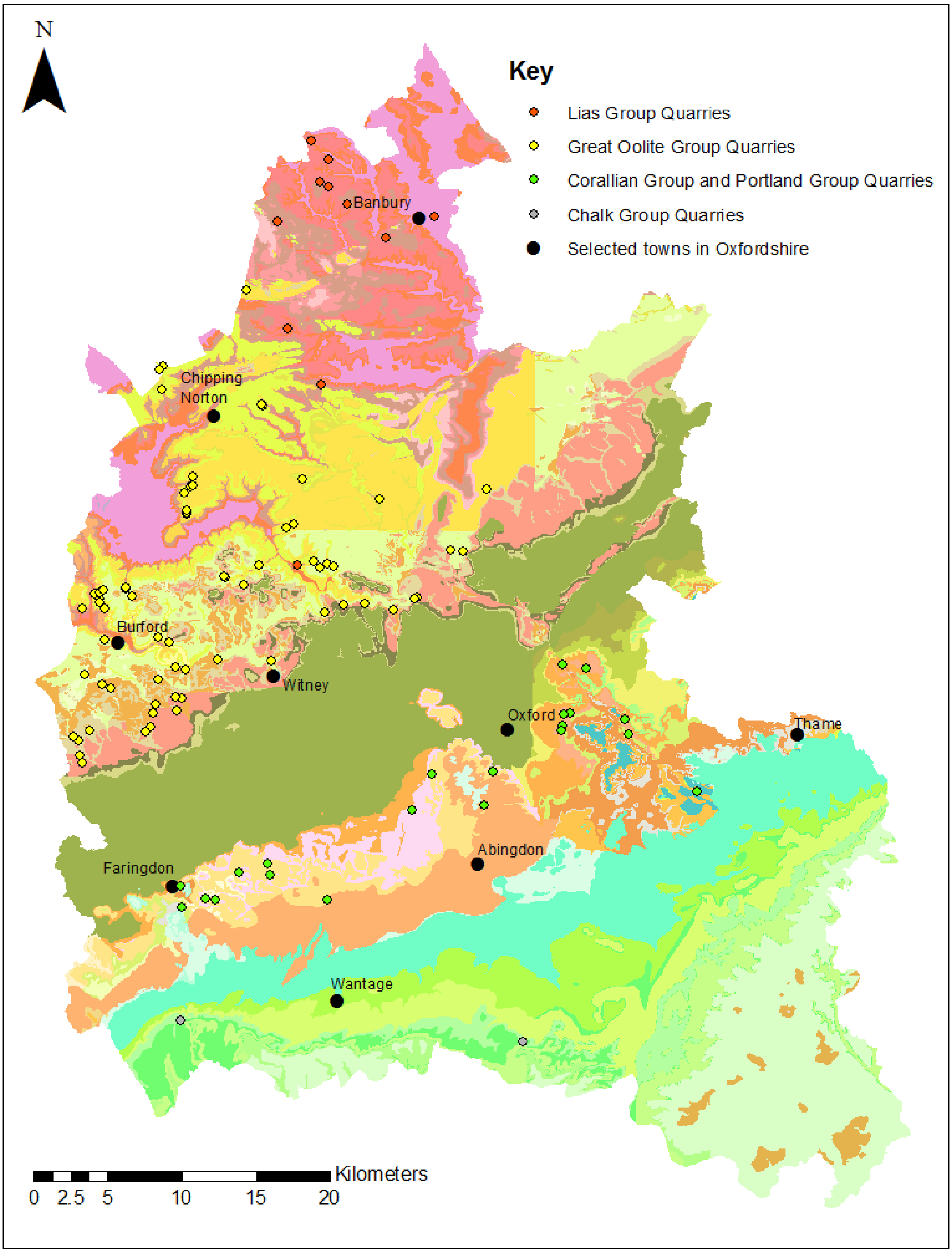

Figure 5. 12: Map showing quarries listed in the Strategic Stone Study database known to have yielded building stone, coloured by outcrop group. © NERC 2017.

Using the data on the region's geology collected in Chapter 3 and Catalogue 1, we can look in more detail at the particular stone formations exploited. Bedrock formations which had quarries dug into them, as recorded in the *BritPits* database of quarries with a known end-use of building stone, were further investigated, Table 5.1 showing the total number of quarries dug into each bedrock, the total area of surface outcrop of each formation in square kilometres, the percentage that this represents of the total area of Oxfordshire, and the rate of quarries per square kilometre seen, with this last statistic then ranked. For the purposes of this exercise those quarries listed as having been dug into the Pusey Flags Member were grouped with their parent formation of the Kingston Formation, and the Stonesfield Slate quarries were grouped with their supposed parent formation of the Taynton Limestone Formation.

Lithostratigraphy	**No. of Quarries**	**Area (km^2)**	**Area as % of Oxfordshire**	**Quarries per km^2**	**Ranked**
Taynton Limestone Formation	28	11.93	0.458	2.35	1
Wheatley Limestone Member	11	8.6	0.33	1.28	2
Marlstone Rock Formation	28	79.83	3.063	0.35	3
Forest Marble Formation	29	102.06	3.916	0.28	4
Salperton Limestone Formation	1	5.37	0.206	0.19	5
Portland Group	3	18.22	0.699	0.16	6
Chipping Norton Limestone Formation	11	69.21	2.656	0.16	7
White Limestone Formation	17	115.64	4.437	0.15	8
Great Oolite Group	12	108.13	4.149	0.11	9
Cornbrash Formation	10	101.22	3.884	0.10	10
Kingston Formation	5	54.15	2.078	0.09	11
Stanford Formation	3	45.71	1.754	0.07	12

Kellaways Sand Member	1	18.38	0.705	0.05	13
Holywell Nodular Chalk Formation	1	75.72	2.906	0.01	14
Dyrham Formation	1	76.53	2.937	0.01	15
Charmouth Mudstone Formation	1	106.56	4.089	0.01	16

Table 5. 1: Ranking of geological formations by known building stone quarries (BritPits database) per area of stone outcrop.

Whilst the top five geological bedrocks by quarry numbers were the Forest Marble Formation, the Marlstone Rock Formation, the Taynton Limestone Formation, the White Limestone Formation, and the Great Oolite Group, these do not correspond to the highest ranked when divided by the area of total outcrop of that formation, and the rate of quarries per km^2 varies hugely, from 2.35 per km^2 and 1.28 per km^2 for the top two ranked rock types, dropping drastically down to 0.35 quarries per km^2 for position three. This leaves the Taynton Limestone Formation and the Wheatley Limestone Member, the latter merely a *member* level component of the Stanford Formation, standing out for their high density of quarries. This can be fairly easily explained: the Taynton Limestone Formation has 20 Stonesfield Slate pits in that number, numerous, although probably each quite small, on account of the economic importance and wide distribution of this roofing material, something demonstrated by Horsfield *et al.*[405] In addition the Taynton stone is regarded as perhaps the best freestone in the region. The location of the Wheatley Limestone outcrop, in the direct vicinity of Oxford, and the frequent use of this stone in construction of Oxford college buildings, due to its proximity as well as its relatively favourable material properties, led to the development of a number of quarries in a small area, on a stone type outcropping under only 0.3% of the county.

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[405] Horsfield *et al.* (2013) Fig. 3.

5.2.4. Landscape Approaches to Exploring Stone Extraction in Oxfordshire

As demonstrated by these hypotheses for the popularity of the Taynton and Wheatley stones, factors which might be considered to have impacted on the choice of stone include the physical attributes of the stone being quarried, as well as the ease of accessibility and ease of transport to sites of use. In this section we will consider the primary factors impacting the location of quarries, leaving for Chapter 6 detailed discussion of the factors which relate to the movement of stone onwards to its markets and points of use, and the transport means available.

5.2.4.1. Stone Quality

The first question to ask is, what can we say about the attributes Roman surveyors or masons might have sought in looking for building stones? Vitruvius offers some general comments on the choice of stone: he acknowledges that stone is not available in all regions (II.6.5), and that stones differ significantly (II.7.1). The hardness of stones and their resilience to weathering are the key physical attributes which interest him (II.7.1-5), implying that workability (further highlighted in his description of the close texture of Anician stone, II.7.3), strength, and resistance to water, frost, and fire damage were his main considerations when choosing stone. He also acknowledges that proximity to stone sources often determines the choice of stone, stating that at Rome they would have used Anician stone if it was available closer, but as it was not, that stone from Grotta Rossa and Palla was of necessity used (II.7.5).

These are sensible practical considerations for stone choice: its strength, its resistance to weathering, how readily it can be turned into desired block sizes or shapes, how finely it can be finished, and its accessibility, all in relation to the desired use, i.e. the building techniques being used, are key.

Additionally, the character of a stone deposit will dictate the maximum dimensions of stone that can be extracted. The depth of facies and spacing of bedding planes, and the frequency of transverse fissures or faults creating breaks or lines of weakness, are major considerations for the mason looking for suitable stone. As Peter Rockwell notes, some of these aspects can be observed in the quarry, but sometimes will only become apparent once a mason has started to work with a stone.[406]

Within many of the limestone and sandstone outcrops in Oxfordshire there will be variation of these factors, and a broad spectrum of stone qualities, from good quality freestones occurring in thick strata for making large blocks, through to flaggy, fossiliferous, irregularly fractured deposits, only useable for rubble, and not for freestone or important structural blocks such as quoins or lintels. For example the Taynton Stone Formation is well known for providing excellent freestone, having facies of well-cemented coarse-grained, cross-bedded ooidal limestone, particularly quarried in the vicinity of Burford and Taynton, which has been used in the construction of the 15th C. Divinity School in Oxford, and for quoins and lintels across the north of the county. Richardson notes that where it is exposed in the cutting through which Akeman Street was dug at the ford of the Evenlode south of Stonesfield, the stone is flaggy and fissile, and usable only for rubble walling.[407] Thus an understanding of the qualities of particular stones cannot be obtained simply from geology maps alone. Analyses of historical descriptions of quarry sequences, together with fresh field surveys (sadly something beyond the scope of this thesis) are necessary for approaching this subject, and the best source for these data are the BGS Memoirs accompanying the Geological map sheets, rather than the sheets themselves.[408] Given the similarities between the characteristics a Roman mason was

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[406] Rockwell (2013).
[407] Richardson *et al.* (1946) 34; Horsfield (2011) 4.
[408] Richardson *et al.* (1946); Horton *et al.* (1995).

looking for and those a medieval one might have sought, the pattern of historical quarries goes some way to showing where stone of attractive qualities is found (Fig. 5.13).

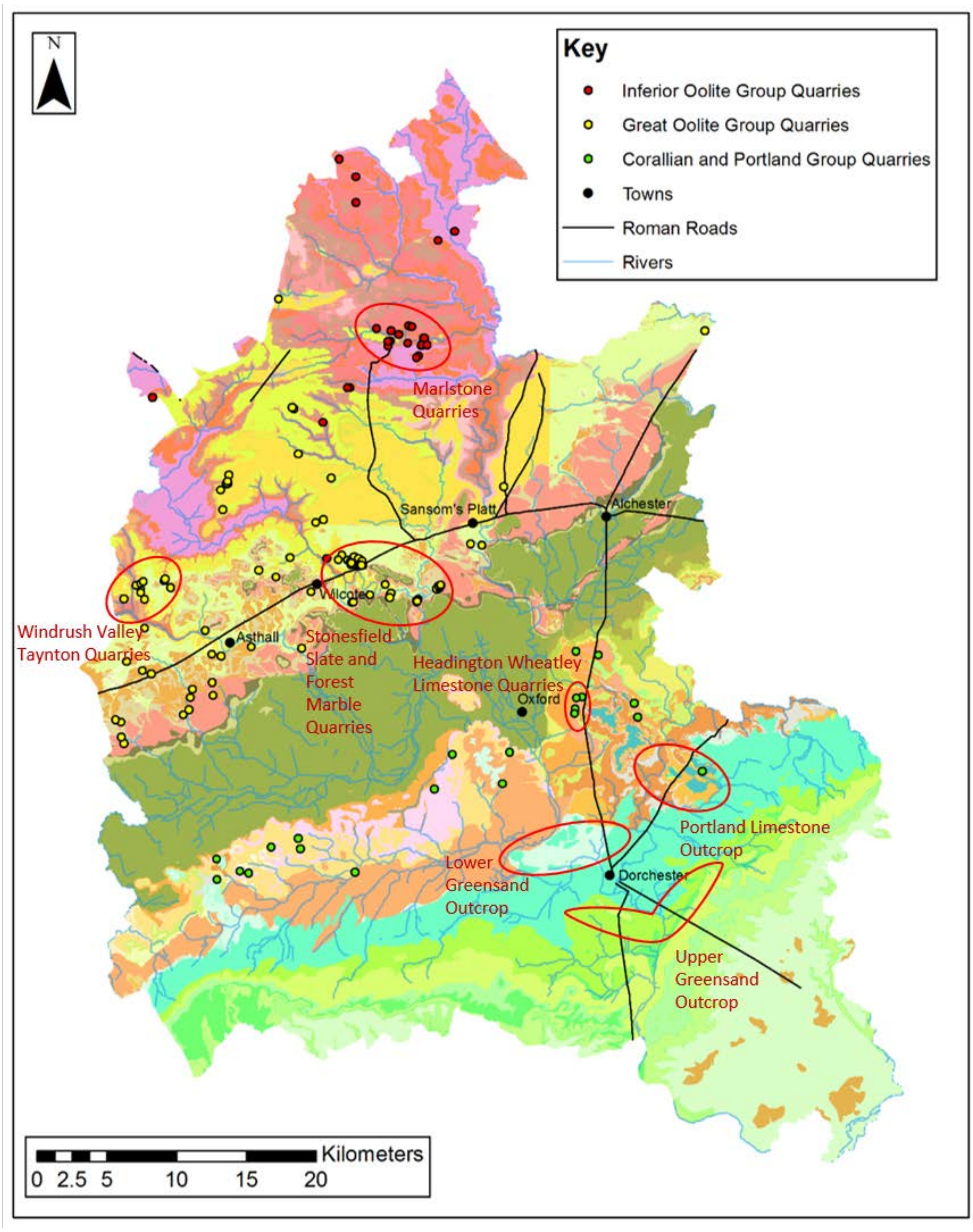

Figure 5. 13: Major medieval and post-medieval quarry groups in Oxfordshire (based on the BRITPits database), and stone outcrops possibly exploited for construction at Roman Dorchester. (BRITPits data © NERC).

5.2.4.2. Surveying for Stone

The second question to ask is how such stones were discovered, given the lack of significant stoneworking in southern and central Britain prior to the Roman period, and thus presumably the lack of a pre-existing knowledge of stone sources. Blagg, Pearson, and Hayward all pose suggestions for how particular sources might have been discovered for exploitation, with a military role figuring significantly.[409] The very first Romans to travel around Oxfordshire with a potential interest in or knowledge of sourcing stone, and the first to conduct informal or formal surveys of the landscape, would have come with the army, exploring for purposes of conquest and security, but also for planning the construction of communication and supply networks, assessing strategic control of the territory, and potentially considering resource acquisition for the creation of new administrative centres.

Thus road and fort building may have led to broad surveys, expeditions being sent out from army bases to piece together an understanding of the lay of the land and to report on the availability of important resources such as water, timber and potentially, stone. Whilst the construction of many forts and other military buildings was not undertaken in stone until c. 50 years or more after the initial conquest, the military were making use of stone for the creation of tomb stones and altars immediately on arrival.[410] Their masons might therefore have been on the look-out for good quality freestones which could be carved into the required forms with appropriate fineness and precision, and some of the stones available in the Cotswolds were certainly apt for this. Between Cirencester, Gloucester, and Bath several excellent freestones are known to have been exploited by the Romans and in later periods.[411]

One suggestion which Hayward makes is that oolitic limestones from the Cotswolds might have immediately been identified and used on account of their great similarity to limestones outcropping in Roman Gaul, which were already widely in use in Gallia Belgica,

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[409] Blagg (1990) 35-37; Pearson (2006) 16-18; Hayward (2009) 94-103.
[410] Blagg (1990) 34; Hayward (2009) 40-42.
[411] Hayward (2009) 76-77 and Fig. 5.1.

Gallia Lugdunensis, and the two Germanies.[412] Calcaires à polypiers stone, quarried at Norroy, Gallia Belgica, was distributed throughout that province as well as the two Germanies, using the Rhine, Moselle, and Meuse to travel.[413] This stone is almost identical in age, lithology, and character, to the Great Oolites of the Cotswolds. Could the Oxfordshire stone have been recognised by individuals, most likely in the military, who had come from Gaul or Germany? The above quoted inscription from Bath, concerning a stonemason named Priscus, who describes himself as a member of the Carnutes, in central Gaul, is fascinating in part because his homeland and Bath both have outcrops of very similar Jurassic oolitic limestones.[414]

Of the legions which took part in the invasion of Britain, Legio II Augusta came from its base in Strasbourg, Germania Superior, and in the AD 60s and 70s was known to have been stationed at Gloucester, just to the west of the Cotswolds, and the legion can certainly be linked with Alchester, in north Oxfordshire, up against the eastern end of the Cotswolds.[415] Legio XIV Gemina, previously based in Mainz, again in Germania Superior, also spent time in the few decades after conquest based in the midlands, firstly at Mancetter, Warwickshire, and then at Wroxeter, Shropshire. Legio XX Valeria Victrix, having been based in Neuss, Germania Inferior, during Tiberius' reign, can be traced to having had detachments based at Gloucester, having had soldiers take part in the battle with Boudicca's forces at Mancetter in AD 60/61, and having been based at Wroxeter. Hayward notes the use of Calcaires à polypiers by the Legio XX at both its base in Neuss as well as in England, and the role of the military in quarrying on the Rhine frontier.[416]

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[412] Hayward (2009) 113.

[413] Hayward (2009) 95.

[414] *RIB* 149.

[415] Sauer (2005b).

[416] Dworakowska (1983); Stribrny (1987); Hayward (2009) 113.

In addition an array of auxiliary forces were present in the region, including the Ala Gallorum Indiana, presumably raised somewhere in Gaul, attested at Cirencester.[417] Amongst all of these forces would have travelled individuals with skill and experience as masons. It seems reasonable that, given the prior stations of these troops in regions making use of oolitic limestone, masons would have recognised Cotswold Great Oolites as suitable for use, correctly predicting that, given their similarity to the French stone, their properties would be favourable.

Considering the impact such military involvement might have had in Oxfordshire, the construction of the road between Alchester and Cirencester would undoubtedly have led to the discovery of stone outcrops, particularly where the road was cut into hillsides, as at its descents and ascents into and out of the river valleys of the Evenlode and Windrush. The construction of early forts, certainly at Alchester, and as hypothesised at Dorchester, would also have given the military the opportunity to survey for stone in explorations of the landscape.[418]

Interestingly, it is not in fact military but public architecture which was the first major consumer of stone in Britain. Major military works in stone do not appear with any frequency until the early 2nd century AD, when bathhouses, granaries, and ramparts begun to be constructed in stone, such as at the forts at Chester, Caerleon, and Inchtuthil.[419]

Major municipal building projects seem to have been started earlier: significant consumers of stone already by c. AD 100 included the Temple of Claudius at Colchester, begun in the late AD 40s or early 50s (using stone thought to have been quarried at Ham Hill, Somerset); at Bath the temple complex to Sulis Minerva, under construction from c. AD 65 using the excellent locally available Bathonian oolitic limestones, with Blagg suggesting

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[417] *RIB* 108; Sauer (2007).

[418] Sauer *et al.* (1999); Frere (1962)

[419] Pearson (2006) 18.

that imported labour and expertise was used for quarrying and construction; the forum-basilica complex at London, built c. AD 70 and significantly enlarged at the end of the 1st century; the forum-basilica complex at Silchester, possibly started in the Neronian period; the forum, basilica, temple precinct, and theatre built at Canterbury in the late 1st/early 2nd centuries; and the forum-basilica, public bathhouse, *macellum*, and metalled street grid at St Albans, also all dating to the later 1st century.[420]

Much of this work might have involved military support in some way or other. Perhaps, as suggested above, quarries were identified, and even opened and worked, by the military, who could then provide stone to the administrators and magistrates of the province for their projects; the roads and other aspects of the communication network, constructed and managed, at least initially, by the military, facilitated the movement of stone over short and long distances far more easily. Yet we must consider that forms of municipal and private surveying and exploitation would have come to dominate stone production in Oxfordshire, and in Britain as a whole. After all land ownership seems to have granted the legal right for exploitation of the mineral resources of that land, and control of access and distribution of those products.[421] The numerous villas of the Cotswolds made use of the high quality stones available in their immediate vicinity, presumably quarried as and when needed from workable outcrops within the land of the owner.[422] At Alchester the increasing use of stone is noted from excavations, and construction of buildings such as the possible extra-mural bathhouse, the possible temple, and other structures within the walls, together with the building of the stone walls themselves sometime in the late 3rd century, would all have created considerable, if perhaps sporadic (see below, Chapter 7), demand for quantities of stone.[423] At Dorchester there appears to be less construction in

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[420] Blagg (1980) 106; Wacher (1995) 193-4; Niblett (2001) 77-8; Pearson (2006) 18.

[421] Ulpian *Digesta* VIII.4.13.1.

[422] E.g. Ditchley: Radford (1936), Booth (1999b); Shakenoak: Brodribb *et al.* (2005).

[423] Young (1975); Booth *et al.* (2002); Sauer (2007).

stone within the walls, and as yet no evidence of significant administrative or other public buildings; however, some stone construction in stone is still seen with intra-mural buildings built in the 2nd and 3rd centuries, and the construction of the town walls themselves, again sometime in the late 3rd century, will have created significant demand for stone, which would most likely have needed to have been met through local municipal or private extraction.[424] As Russell notes, the development of Roman patterns of elite self-display amongst the Romano-British population necessitated the development of stone extraction by the local elites, either privately or in the fulfilment of magisterial duties.[425]

5.2.4.3. Quarrying Considerations

The third and final question to address here concerns the location of quarries, once regions of usable stone have been surveyed and identified. Topographical, logistical, and market considerations might all play a part.

Quarrying is made significantly easier if a steep face already exists into which to quarry, as opposed to having to dig a pit downwards into the rock. That initial steep face may facilitate the discovery of the stone in the first place, and such faces permit the identification of particularly suitable strata with much less effort. Material that is extracted from such a quarry face can be removed from the bottom of the face, whereas vertically dug quarries need to raise quarried material up and out of the pit, requiring far more energy and investment in labour and equipment. It might be hypothesised therefore that Roman quarries would have preferentially been located in such advantageous sites.

In order to find such steep slopes, digital terrain models and geomorphological studies offer great potential. An example of a high resolution geomorphological study recently published is that of Baroni *et al.* on the quarries of Carrara.[426] Using traditional

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[424] Frere (1962); (1984); Booth (2013).
[425] Russell (2013a) 38.
[426] Baroni *et al.* (2010).

topographic maps combined in a GIS with orthophotos, GPS field surveys, and aerial photographs, they created a geomporphological model and relief model for the region, within which they symbolised the major anthropogenic activities (quarrying, as seen through successive quarry faces, and waste dumping to form the *raveneti*) and natural processes (vegetation cover, debris flows, and landslides). Analysis of the model allowed identification of sources of present day risk associated with the landscape, but also exploration of the "geological-cultural archive represented by the anthropogenic landforms and deposits in the quarry basins of Carrara."[427]

For discovering the sites of past quarries across a wider region, for example Oxfordshire, it is not possible to construct such a detailed topographical map with the resources of this project, and so the Ordnance Survey 5 m resolution digital terrain model has been used. The topographical location of the known historical quarries has been investigated, and in particular the vicinity of quarries to river valleys and other slopes in the county analysed.

In Oxfordshire's relatively smooth, rolling landscape, the steepest slopes of the county tend to be in the cuts of river valleys. The valleys of the Evenlode and Windrush are particularly prominent, and the high concentrations of extraction of Taynton Stone around its type site and Burford, and the extraction of Stonesfield Slate at Stonesfield, might be explained in part by the presence of the steep valley sides at these locations, as well as the good quality of the stone available. The locations of quarries for Wheatley Limestone in Headington, and for Portland Limestone and Sandstone in the vicinity of the Miltons and at Standhill, also perhaps fit this pattern, being on hill slopes. Any cuttings for the construction of the Roman roads may also have offered the possibility of easy stone extraction, and thus we can look along the lines of both Akeman Street running west from Alchester through the Cotswolds, and the line of the road running south from Alchester

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[427] Baroni *et al.* (2010) 242.

to Dorchester, to see that these cross intensively quarried stone outcrops (Fig. 5.14). These include the cluster of Stonesfield Slate quarries close to Akeman Street between Asthall and Wilcote, a cluster of Marlstone Rock quarries in the Swere Valley at the north end of the road running north from Wilcote, and a cluster of Wheatley Limestone quarries about half way between Dorchester and Towcester, in modern Headington. Unpicking the relationship between these probably post medieval quarries and the Roman roads is difficult. The Roman roads might have continued in use through to this period, facilitating easy onward movement of the material, but it is also possible that Roman exploitation of stone outcrops in these locations has seen continuity into the post medieval period, the hard work having been done in locating the outcrops, starting a quarry face, and providing transport links by road or possibly river, something which will be discussed further below (Chapter 6).

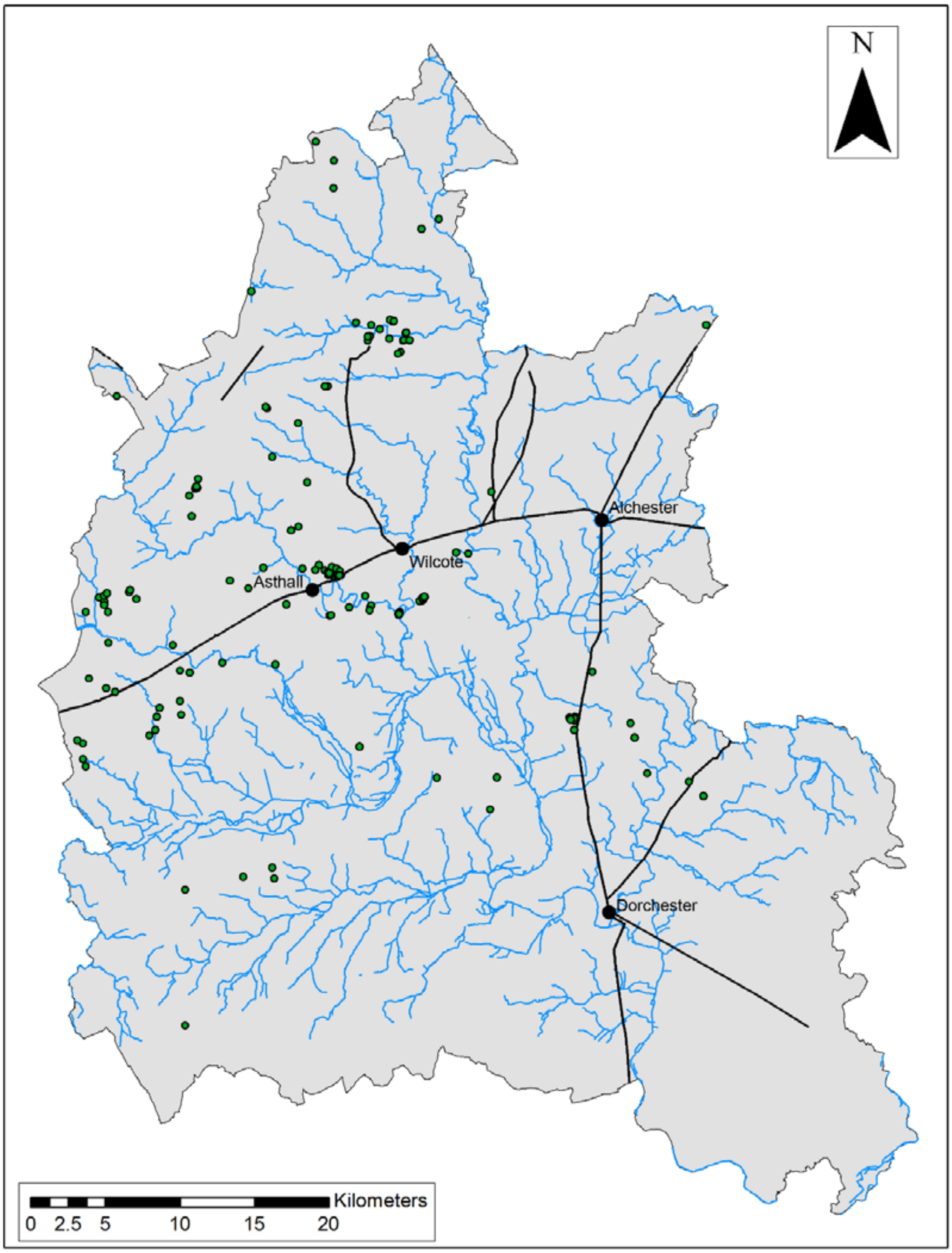

Figure 5. 14: BritPits historical building stone quarries mapped with the river network and Roman roads in Oxfordshire.

5.3. Earth Extraction

Locating the sites of ancient soil extraction is a challenging task. It is an activity which is very rarely looked for, stemming from the broad lack of discovery of, and resultant interest in, earth architecture. Vindolanda Tablet 156 records the activity of a group of soldiers, possibly 19, assigned to the task of digging *lutum*, clay or mud, for the construction of the wattle fences of the camp.[428] On the basis that a single man might be able to excavate between 1 and 2 m^3 per day, this team of 19 soldiers might produce 20 – 30 m^3 of earth, which, at a density of 1200-1300 kg/m^3, equates to c. 24 – 40 tonnes. The act of gathering, loading (perhaps into baskets) and transporting the soil would significantly reduce this rate, perhaps even halving it, but this goes to show the relative ease with which earth for construction could be gathered with a small group.

Some pits have been linked with this function. Perring and Roskams identify this practice in Roman London, builders apparently exploiting the London brickearth (and not the London Clay bedrock, which was too plastic); just across the Channel a similar function is assigned to pits dug adjacent to Roman buildings in Tongeren, Flanders; and Clement identifies such activity in Lyon.[429] In Oxfordshire such things have not been expressly identified.

Understanding that a pit explicitly represents building material extraction is difficult, given that there is unlikely to be any positive evidence that it was the soil which was sought-after in the digging of the pit; many other interpretations for a pit are possible, for example that is was dug for refuse disposal (and pits dug for earth extraction might subsequently be used as refuse pits). Earth is relatively ubiquitous, and hence less economically valuable: as such localised extraction for individual building projects might

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[428] Vindolanda Tablet 156, lines 5-6.

[429] Perring and Roskams (1991) 67 and 117; De Clerq (pers. comm. 17/5/17); Clement (2016) 146-155.

be expected, being more viable than large scale centralised acquisition of this material. Thus our best chance for offering an interpretation of a pit as having been for earth extraction is if it is in the direct vicinity of an earth-built structure. Earth extraction pits should be sought, and their possible existence borne in mind by all excavators working on sites where earth architecture is a possibility, so that we might start to identify them more frequently and understand better any clues which might aid their identification.

5.4. Brick- and Tile-Production in Oxfordshire

As noted above, no Roman tile or brick production sites have been excavated in Oxfordshire, with only one site identified from field walking and a geophysical survey at North Leigh.[430] Thus our understanding of the regional mechanisms of clay extraction, processing, and firing for making these products is necessarily founded on a broader base of evidence from surrounding counties. Pottery production is well attested in Oxfordshire, with the noted Oxford Roman pottery industry, and thus we can gain some insight from this as another ceramics industry, although operating with key differences.[431] As with the examination of building stone, we can also look to subsequent periods for insight into the Roman.

5.4.1. Clay Extraction and Processing, and Fuel Acquisition

Beginning with material extraction, as with the extractive pits for soil, those for clay are difficult to identify. Being dug into soft, often low-lying parts of landscapes, pits would rapidly collapse and fill to leave subtle archaeological features rarely visible in field survey. In excavation, again the purpose of such a pit will not be easily defined. Roman clay extraction sites are rarely discussed with regard to CBM production, and so we only have limited sources of evidence. Clay extraction pits in the context of large-scale pottery production are another possible avenue for investigation to assist this project, but again these have only seen low levels of analysis.[432]

Clay pits identified for ceramic production are almost always within a short distance of a kiln, indeed sometimes directly around the kilns, as at Rushden, Northamptonshire.[433] Occasional exceptions do exist, for example the use of white pipe-clays for making

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[430] Speake (2012) 76.
[431] Young (1977) 9-50.
[432] Swan (1984) 43-45.
[433] Swan (1984) 43.

mortaria in the Oxford industry, the clay coming from Shotover Hill, the kilns sited two or three km away in Headington.[434] Nonetheless this usual close relationship is unsurprising, partly on account of a severe excavation and identification bias: we have generally only looked for clay pits near to kilns, and we are often only able to identify them as clay extraction pits because of their proximity to the kiln. The location of pits in the direct vicinity of the kiln has clear benefits: clay is a relatively heavy material when wet, and is needed in such large quantities for brick- and tile-making that moving it any significant distance will entail a significant cost in labour and logistics. Movement of the finished product is likely to be cheaper than movement of the raw material, so positioning kilns close to the clay source is more advantageous than being proximate to the point of use.

As discussed above (Chapters 3.2.1 and 4.2.1.) particular clay sources might be more or less suitable for brick production. The particular properties of the clay which impact this might include factors such as proportions of different clay minerals, the presence and concentrations of inclusions, metal oxides, and organic content. Whether a clay might be suitable for CBM manufacture is difficult to understand from petrological descriptions alone however, and so, (without the resources for a program of field sampling and experimental firings), looking at the location of later brick and tile production in the county furnishes useful insight. Today there is no commercial brick or tile production in Oxfordshire, but neighbouring counties are exploiting geological strata, which also occur in Oxfordshire, for this; the *BritPits* database furnishes details of historical, now closed, production sites.

From neighbouring counties today we can see the use of the superficial Clay-with-Flints in Buckinghamshire, the Oxford Clay Formation and Kimmeridge Clay Formation in

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[434] Young (1977) 16; Swan (1984) 43.

Wiltshire, the Gault Clay Formation and Reading Clay Formation in Hampshire, and the Oxford Clay Formation and the Gault Clay Formation in Bedfordshire.[435] The BritPits database contains records of 161 historical brick and tile production sites in the county, utilising a variety of bedrock and superficial clays, as shown by Fig. 5.15. The 54 extractive sites exploiting superficial deposits made use of a range of clays, including the Neogene Clay-with-Flints, and the Quaternary Northern Drift Formation, and Head Clay. There is just the one site said to have been using Alluvium: the Littleworth Brickyard, near Wheatley, exploiting the alluvial deposits of the River Thame. The 107 sites exploiting Bedrock deposits include 34 on the Lambeth Group in the far south east of the county, 10 on the Gault Formation, 18 on the Kimmeridge and Ampthill Clay Formations, and 12 on the Oxford Clay Formation, suggesting that these clays provide some of the best brick and tile-making resources, at least in the more recent past. The Lower Oxford Clay is particularly noted for its use in brick-making in the post-medieval period, having a high carbon content (up to 6.1% by volume at Calvert, Buckinghamshire) which enables some degree of self-firing, reducing fuel costs.[436] It is perhaps interesting to note that one of the largest Roman tileries known in Britain, at Minety, Wiltshire, is located on the Oxford Clay Formation.

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[435] Norton *et al*. (2004).

[436] The so-called *Fletton Process*. Horton *et al*. (1995) 23.

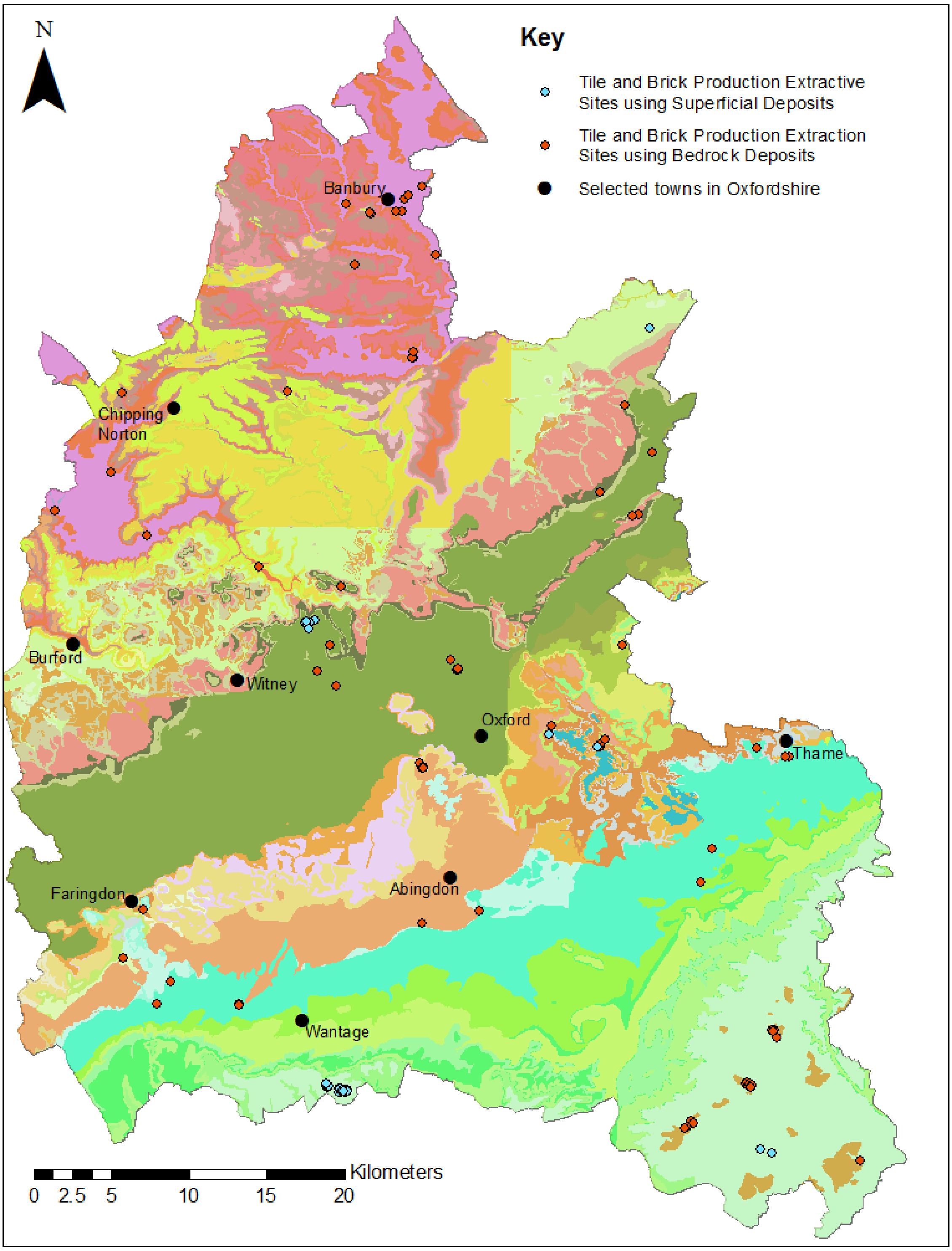

Figure 5. 15: Historical brick production sites set against the Oxfordshire bedrock geology, and symbolised by whether they are recorded as using bedrock or superficial clays. Data from the BritPits database and the British Geological Survey, © NERC 2017.

Clay is rarely used immediately after extraction and in its natural state, as raw clay's material properties are seldom ideal for use in ceramic production. As noted in Chapter 3.2.1, clay might undergo a range of processes, including souring, soaking, levigating, treading, and tempering, in order to improve its properties for forming, drying, and firing.[437] All of these processes require spaces for this activity and storage of the materials, and soaking and tempering require additional resources: water, and the tempering material, be it sand or other minerals, shell, grog (crushed ceramic), or organics such as chaff. Thus at clay extraction and kiln sites we might find additional infrastructure such as tanks, containers, and working floors, possibly workshops, and traces of tempering material. Examples of sites where these have been found for pottery production include at Pitts Wood in the New Forest, where two distinct piles of different coloured clays, along with a red earth, were found ready for mixing, with a third heap already mixed; at Verulam Hills Field, St Albans, a series of rectangular pits interconnected with water channels are interpreted as settling tanks for levigation; and at several of the Oxford potteries well-built "clay chests" have been found, rectangular pits lined with clay, stone slabs, or tile.[438] Such features are less well-known for tile production, but one example includes the tilery at Minety, Wiltshire, where alongside at least ten tile kilns, three large clay pits and a rectangular stone building have been found, interpreted as a workshop.[439]

DeLaine and Warry have both considered the question of material and manpower requirements for the production of CBM. DeLaine works on the basis of *bessales*, 20 cm square bricks, c. 3 – 3.5 cm thick, citing that 1000 *bessales* required 1.25 – 1.38 m^3 of clay (or one *bessalis* requiring 1250 – 1380 cm^3).[440] A single *tegula*, based on Warry's average dimensions of 40 cm long, 30 cm wide, 2 cm thick, with 5 cm tall flanges, would require c. 2560 cm^3 of clay; 1000 *tegulae* would require c. 2.56 m^3 of clay. Brodribb's average *tegula* of 43 cm by 33 cm, using the same flange dimensions, would require 3010 cm^3, or c. 3 m^3 for 1000.

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[437] *Cf.* Swan (1984) 44-5.

[438] Wise (1863) 220; Anthony (1968) 21-22; Young (1977) 16-18 and Fig. 17A.

[439] McWhirr (1979b) 102 and Fig. 6.1.

[440] DeLaine (2001) 261-2.

DeLaine cites the rates of production of bricks given by Pegoretti, with one brick roughly equivalent to a Roman *bessalis* able to be produced at about 1000 per day, for a brick-maker plus their assistant.[441] Warry takes evidence from graffiti on *tegulae* from Britain and Germany to suggest that c. 220 tiles might be made in one day by a single person, a believable number given the greater complexity of forming the flanges and cutaways, in comparison to a *bessalis*.[442] Regarding acquiring clay, Warry reckons that the c. 560 – 660 kg of clay required for making 220 *tegulae* would be extracted also in one day by one person, but that a further 3.5 days would be needed for preparing the clay and for the total time spent moving materials around.[443] The freshly formed tiles would need to be dried to a leather-hard texture in order to lower the water content and minimise the risk of failure during firing. Warry notes the existence of large post-built structures directly adjacent to kilns at the sites of Piddington (Northamptonshire), Arbury (Cambridgeshire), and Crookhorn (Hampshire), to which the function of drying sheds, heated by exhaust gases from the kiln, has been attributed, and which would shorten the drying time, something very important in the wet climate of Britain. At the very least covered "hacks" would be needed to keep the rain off.

The final basic material needed for brick and tile production is fuel for firing the kiln, usually wood (rather than charcoal).[444] This is needed in large quantities, as shown by experimental firings of Romano-British pottery kilns run by Geoffrey Bryant in the 50s, 60s, and 70s: the firing of comparatively small pottery kilns (c. 1 m in diameter), for comparatively short lengths of time (c. 20 hours, including cooling), required more than 250 kg of firewood.[445] Firing much larger brick and tile kilns (ranging from 1.8m square up to almost 5 m square), for the much longer soak times needed for these relatively large

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[441] DeLaine (2001) 261; Pegoretti (1869) I 192, 281-3.
[442] Warry (2012) 52.
[443] Warry (2012) Table 5.2.
[444] Bryant (1973) 150.
[445] Bryant (1973) 158.

products (DeLaine cites figures of between 1 and 7.5 days), required very significant quantities of wood indeed, on the scale of multiple tonnes per firing.[446]

DeLaine collects together evidence for brick-kiln firing times and fuel quantities from the 19th and 20th centuries, for kilns of c. 20 m^3 up to c. 125 m^3 in oven volume, giving firing times ranging from 30 – 180 hours and fuel consumption of c. 0.45 tonnes of firewood per 1000 *bessalis* bricks (8 inches square), equivalent to about 1.25 – 1.38 m^3 of raw clay. This amount of clay would make c. 500 *tegulae*, although firing these might require slightly more fuel, *tegulae* being bigger.[447] Warry calculates that, taking an oven of 3 m by 2 m by 2m, relatively typical for Roman Britain, c. 1440 tiles could be fired at once, or c. 3.75 – 4 m^3 of clay, perhaps needing 2 – 3 tonnes of firewood.[448]

The significant weight of firewood needed means that proximity to woodland is likely to be another key factor in the location of a kiln, and the gathering, chopping, storing and drying of wood are likely to be highly significant aspects of the manpower needed for CBM production (*cf.* Fig. 5.17).

5.4.2. Kiln sites

Romano-British brick and tile kilns themselves have received some good analysis, particularly with McWhirr's catalogue of 52 kiln sites identified as having been for CBM production.[449] Since his publication however there has not been an updated publication of such sites. Importantly, Mills has collated a database of Romano-British CBM kilns, based on surveys of the ADS, and the most recent version of this database, publicly available online, last updated in 2005, lists 163 sites.[450]

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[446] McWhirr (1979b) 98; DeLaine (2001) 261-263; Warry (2006) 121 and note 26. Bryant (1973) 150 notes that it is invariably wood, not charcoal, used as fuel; Swan (1984) 6-8 discusses fuel types in more detail.
[447] DeLaine (2001) 261-3 and Table 11.B4.
[448] Warry (2006) 119-120.
[449] McWhirr (1979b).
[450] Mills (2015) URL = http://www.archaeologicalceramics.com/tile-kilns.html (Accessed 15/11/17).

There exists some difficulty in the collation of kilns by product type, and it remains a possibility that some kilns identified as pottery kilns may instead, or as well, have produced CBM, and similarly CBM kilns may also have produced pottery.[451] The vast majority of the 51 kilns catalogued by McWhirr and identified as brick or tile kilns have a rectangular or square shape, one or two flues, and an oven divided into 'corridors' by central supports, holding up the oven floor.[452] Evidence for superstructure style is rare, and Bryant's experimental kiln constructions and firings showed that permanent superstructures, temporary superstructures (put up and taken down with each firing), and even an open kiln with no superstructure were feasible and functional for firing pottery at least.[453]

The database of known Romano-British CBM kilns is not complete, and biases in recovery will have had an impact on the visible distribution, with more kilns found in regions or landscape types which have seen more archaeological investigation. As mentioned above, it seems likely that kilns will often have existed outside of Roman urban zones, being situated in rural areas where access to the raw materials was easier; it has been shown that areas which were Roman urban cores have seen far more archaeological investigation than areas which were rural in the Roman period, and thus our chances of recovering kiln evidence will be reduced.[454] However, the database of 163 sites is large enough to offer some potential for investigating kiln location.

As with the stone quarries above, it is interesting to explore the topographical setting of kilns in order to consider the factors that affected their location, and therefore which played a role in the Roman production of CBM. We will here consider the location of kilns relative to the raw materials needed for CBM production: clay, timber for fuel, and water,

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[451] McWhirr (1979b) 97 and Table 6.1.
[452] McWhirr (1979b) 97-99.
[453] Bryant (1973) 152.
[454] McWhirr (1979b) 102; Holbrook and Morton (2008) 34-36.

before moving on to investigate the setting of kilns relative to settlements and transport networks.

5.4.2.1. Kilns Sites and Geology

The first exercise is the comparison of kiln sites with their underlying geology, both superficial and bedrock, in order to explore the types of clay which might have been available at each site. As noted in Chapter 3.2.4 the term 'clay' is broad, and as remarked above, the exact character of geological formations can vary significantly within the unit. For this exercise the 1:625,000 BGS geological maps were used, giving coverage of the whole of England; through surveying such breadth, the detail of these maps is not as high as could be obtained in a more localised study, with a lower precision in the resolution and characterisation of Groups and Formations. Lithological units, as set out in the data table of the BGS 1:625,000 geological bedrock map, were split into two categories: those whose basic description did include reference to "clay" or "mudstone," and those whose did not. Many units have very broad descriptions, for example the Kellaways Formation, which is described in BGS data as "Mudstone, Siltstone, and Sandstone," or the Lias Group, described as "Mudstone, Siltstone, Limestone and Sandstone;" as a result lithological units whose descriptions contained reference to mudstone or clay cover 63 % of the area of England.

The BGS 1:625,000 map of superficial deposits was also consulted, and the deposits of "alluvium," "brickearth," "glacial sand and gravel," and "till" were chosen as being of special interest for their potential to yield clay which might be suitable for ceramic production. These deposits cover 48 % of England. These chosen deposits were then further interrogated through use of the BGS data on superficial deposit thickness, and the finished map created showing the location of superficial deposits potentially containing clay (with their thickness indicated by the intensity of colour), the location of underlying bedrock layers potentially containing clay, and the location of known Roman CBM kilns from Mills' database, colourised depending on whether they were sited on superficial clay deposits, bedrock clay deposits, or a deposit not identified as containing clay (Fig 5.16).

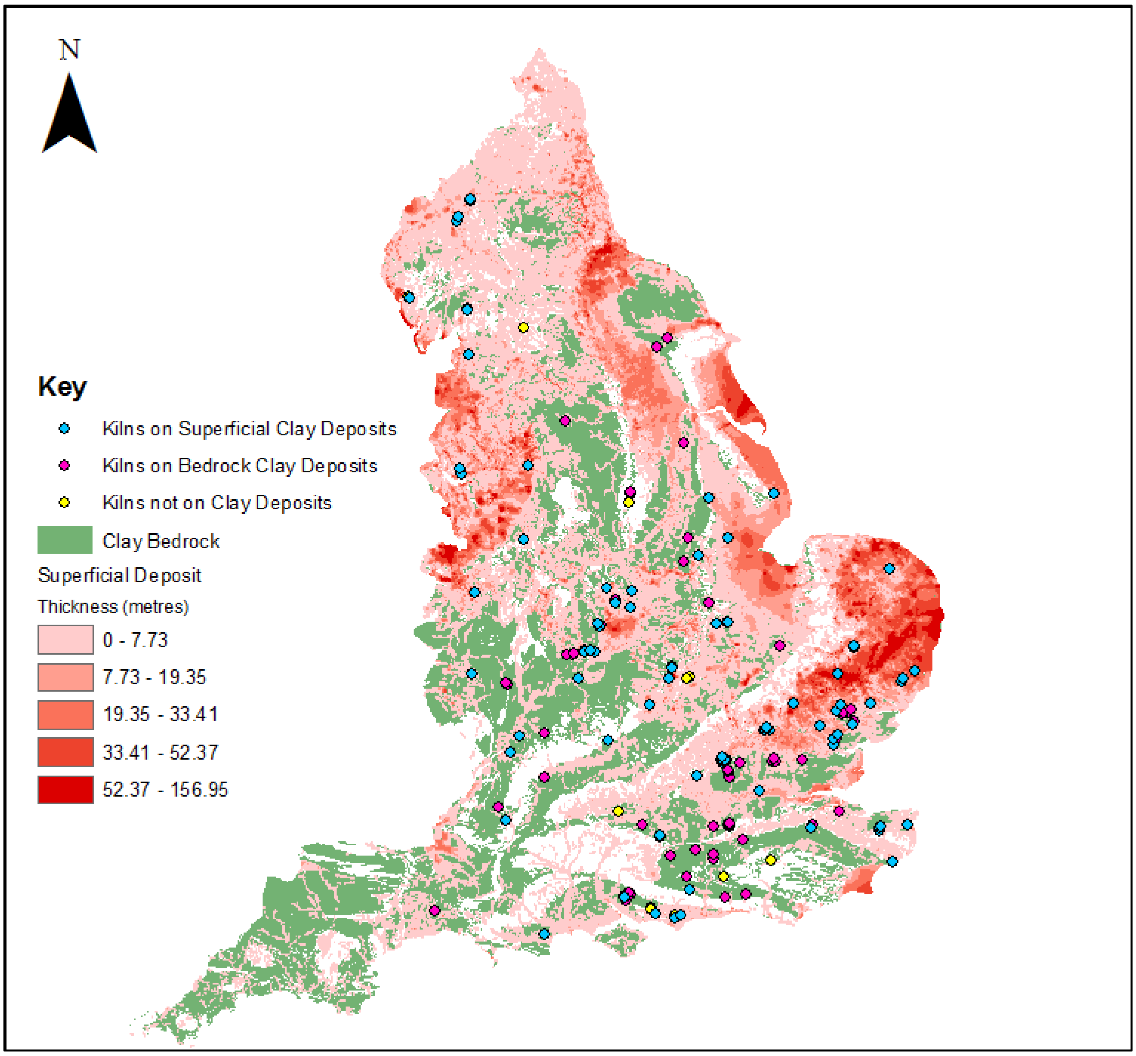

Figure 5. 16: Roman CBM kiln sites in England mapped against bedrock and superficial clay deposits. Kiln data kindly provided by Phil Mills; geological data © NERC 2017.

Of the 163 total kilns, 87 (53 %) lay on superficial deposits potentially bearing clay. 55 of these 87 kilns also overlie clay bearing bedrock, underneath the superficial deposit. The superficial deposits on which these sites were placed ranged in thickness from less than 1 metre to over 26 metres, with an average of 5.77 m. 22 of these 55 were situated on superficial deposits less than 3 m deep, implying access to the underlying clay-bearing bedrock may not have been too difficult if desired.

63 of the 163 CBM kilns (39 %) were built on a site where the outcropping bedrock geological formation did include clay or mudstone, not covered by a superficial deposit, making exploitation of the bedrock for raw clay extraction likely.

11 kiln sites (7 %) were built on sites lacking either superficial or bedrock sources of clay. Those which did not lie on clay-bearing geology were situated between 13 and 674 metres of either a superficial or bedrock outcrop bearing clay, with a mean distance of 296 m. It seems rather likely that all of these sites could therefore have accessed a source of clay with relative ease, and the margin of error for the boundaries of clay deposits would certainly allow for all 11 of these sites to in fact be sitting on a clay deposit of some form.

The conclusions to draw from this analysis include the fact that both superficial and bedrock deposits of clay seem likely to have been used for CBM production, in roughly equal measure.

5.4.2.2. Kiln Sites and Woodland

The second exercise was to compare the locations of CBM kilns with the location of woodland. The locations and sizes of woodland have changed continuously throughout human history, and without a nationwide survey of pollen records and invertebrate studies attempting to gauge the character of ecosystems in the Roman period, perhaps the next best thing we can do is look at the early medieval evidence, from charters, Domesday, and placenames. Roberts and Wrathmell, working on the English Heritage *Atlas of Rural Settlement*, collated data from these sources in order to create a map of the presence of woodland in England, based on the work of Darby, Gelling, Rackham, and others.[455] There are many caveats to any such attempt to use difficult, often problematic evidence, but as

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[455] Darby (1977); Rackham (1990); (2003); Gelling (1984); Roberts and Wrathmell (2000); (2002) 18-24 and Fig. 1.9 and 1.10.; Roberts (2001) 164-167 and Fig. 2.

Roberts states, “although none of this mapping can be wholly accurate the synoptic view is of value.”[456]

The map used here is based on Robert and Wrathmell’s map, as digitised by Dr Chris Green for the *EngLaID Project* based at the University of Oxford, turning the authors’ tripartite symbology of “very large areas of woodland”, “large areas of woodland”, and “other references” into a kernel density estimate plot (Fig. 5.17). This was then compared with Mills’ database of kiln sites. The average distance between kilns and their nearest patch of woodland as mapped is 1.3 km, with a range of 0 to 17.0 km and a standard deviation of 2.9 km. The average Euclidean distance between any point in England and its nearest patch of woodland is 5.6 km, with a range of 0 to 88.9 km and a standard deviation of 9.1 km. Thus it appears that the hypothesis that kilns were more likely to be located close to woodlands is true, with quite a strong correlation.

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[456] Roberts (2001) 167.

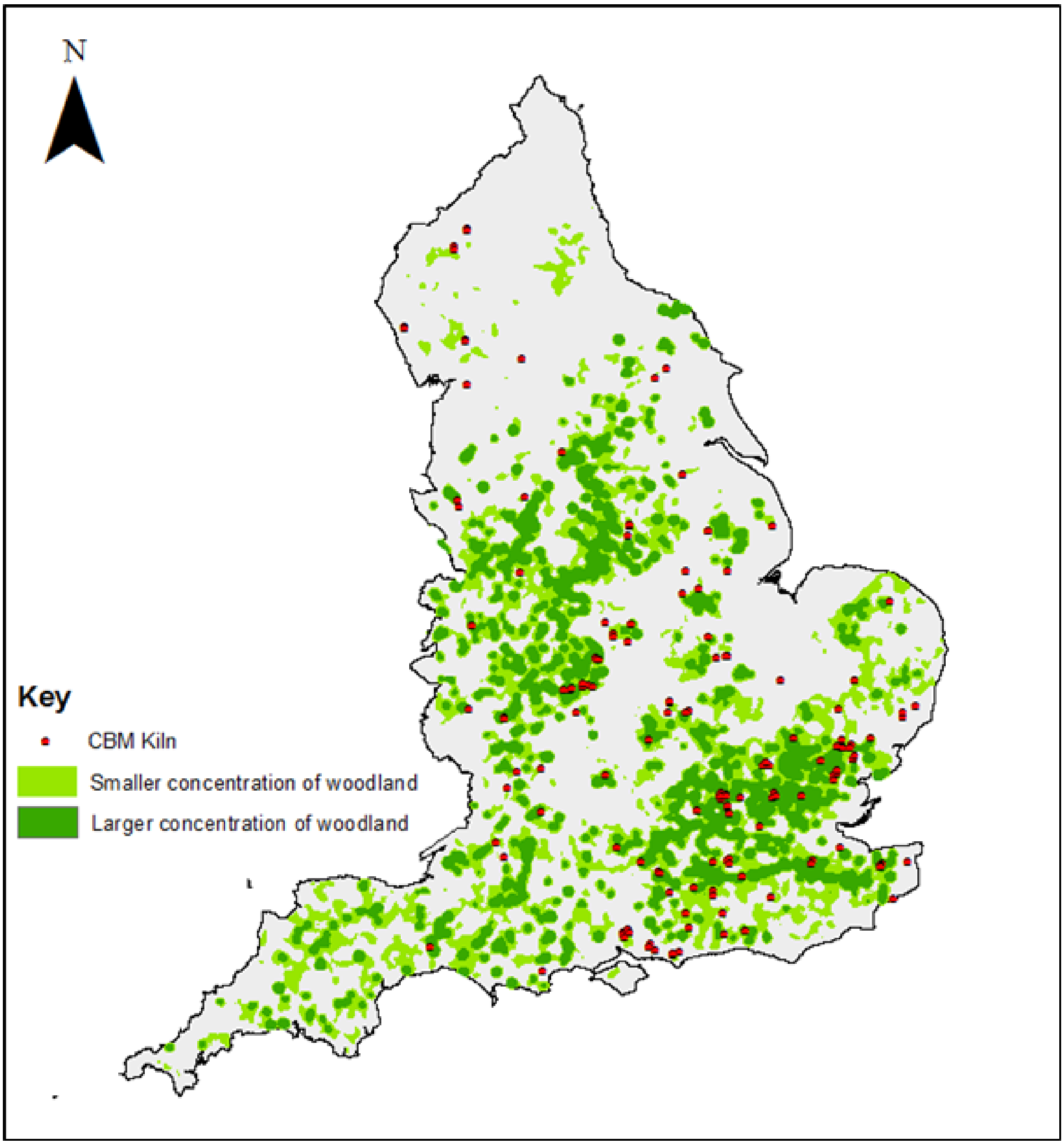

Figure 5. 17: Roman CBM kiln sites in England mapped against historical woodland as plotted by the EngLaID Project, after Roberts and Wrathmell (2000).

Particular concentrations of kiln sites can be seen in the areas of woodland which roughly correlate with the later Royal Forests of Cannock, Arden, Essex, and Windsor, whilst very few kiln sites appear in areas which offer only slim evidence of woodland.

5.4.2.3. Kiln Sites and Roads and Towns

A third factor against which to compare kiln location is that of vicinity to Roman roads and towns, providing the accessibility and demand for the kiln (Fig. 5.18). More details of transport considerations will follow in the next chapter, but given the relatively early date for many of Roman Britain's main roads and major settlements, it is worth considering how these will have affected the location of kilns. Roman settlements were mapped using data from the Pleiades Gazeteer, whilst Roman Road data was obtained from the Historic Environment Record.

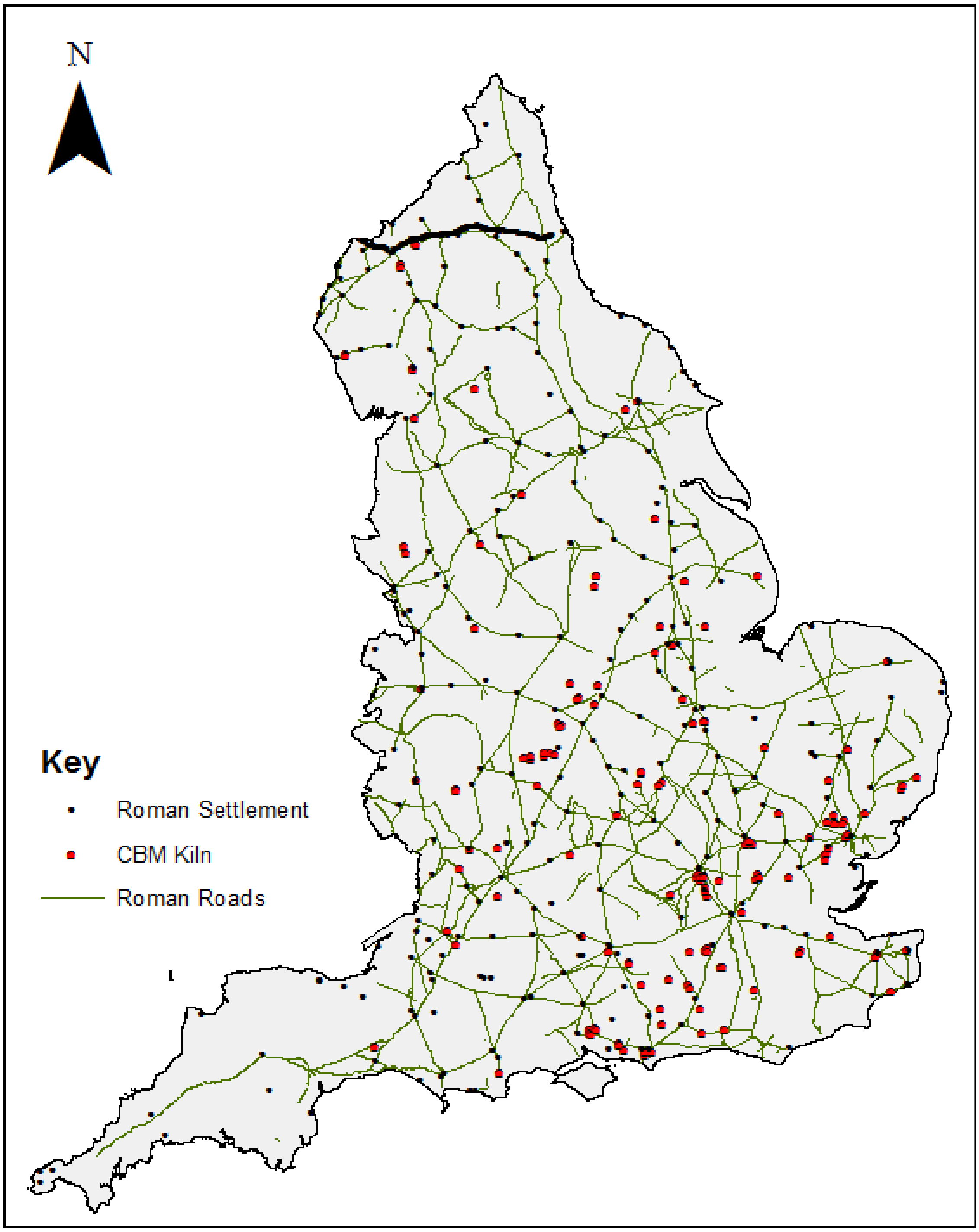

Figure 5. 18: Roman CBM kiln sites in England mapped against major Roman roads and towns. Town data from the Pleiades Project; Roman road data © Historic England 2017.

Some clusters around major Roman towns can be identified, such as to the south of St Albans, Roman *Verulamium*, south of Chichester, Roman *Noviomagus*, and west of Colchester, Roman *Camolodunum*. The relationship between kilns and towns can be tested, again using Euclidean Distance measurements: the average distance between any point in England and one of these Roman settlements is 12.3 km with a standard deviation of 7 km, whilst the average distance between the kiln sites and their nearest Roman settlement is 8.6 km, with a range of 200 m to 33.2 km, and a standard deviation of 5.7 km, suggesting a slight focus towards the towns, but that they do not provide an overwhelming draw. This is interesting, and backs up the hypotheses above that kilns may be situated at some distance from towns, rather than being in the direct hinterland, and this relationship will be discussed further below in an analysis of the proximity of kiln sites to higher status rural sites.

In relation to the roads, a distinct line of kilns along Watling Street, just south of Verulamium, is apparent, and across the country as a whole there is again a slight focus of the kilns towards the roads: the average distance between any point in England and the mapped Roman roads is 5.7 km with a standard deviation of 6.4 km, whilst the average distance between a CBM kiln and its nearest road is 3.3 km, with a range of 49 m to 14.75 km, standard deviation of 3.6 km. Regarding both the relationship of the settlements and the roads with the kilns, there are clear reasons why the latter might be located near to the former, but we must also remember the increased likelihood of uncovering Roman sites nearer to Roman settlements and roads, as set out in Holbrook and Morton, as a result of the higher number of interventions.[457]

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[457] Holbrook and Morton (2008) Fig. 12 and Fig. 13.

5.4.2.4. Kiln Sites and Rivers

The location of kiln sites can be analysed for their proximity to rivers, reflecting to a lesser extent perhaps the use of water in CBM production, but more so the importance of rivers for material transport, as will be discussed in more detail below (Chapter 6.1.1.2 and 6.2.3) (Fig. 5.19). For this exercise the “Main Rivers” map, produced by the UK Environment Agency, has been used. This dataset contains watercourses designated as “main rivers” by the UK EA, being larger rivers and streams. There are, as always, caveats to using this dataset: the route of some watercourses has changed since antiquity, on account of canalisation or other engineering works, and the designation for inclusion in this dataset is based in part on considerations of flood risk and water management, rather than just size.

Again the average Euclidean distance between any point in England and its nearest river was calculated, coming out as 1.82 km, with a standard deviation of 2.13 km, compared to the average distance between kilns and their nearest river being 1.16 km, with a range of 12 m to 5.48 km and a standard deviation of 1.2 km. Again then we perhaps see a slight preference for the locating of kiln sites relatively near to rivers, and the provision of water for making the ceramic products, or the use of waterways for transport are possible explanations for this, although this does not appear to be a particularly convincing relationship in this limited analysis.

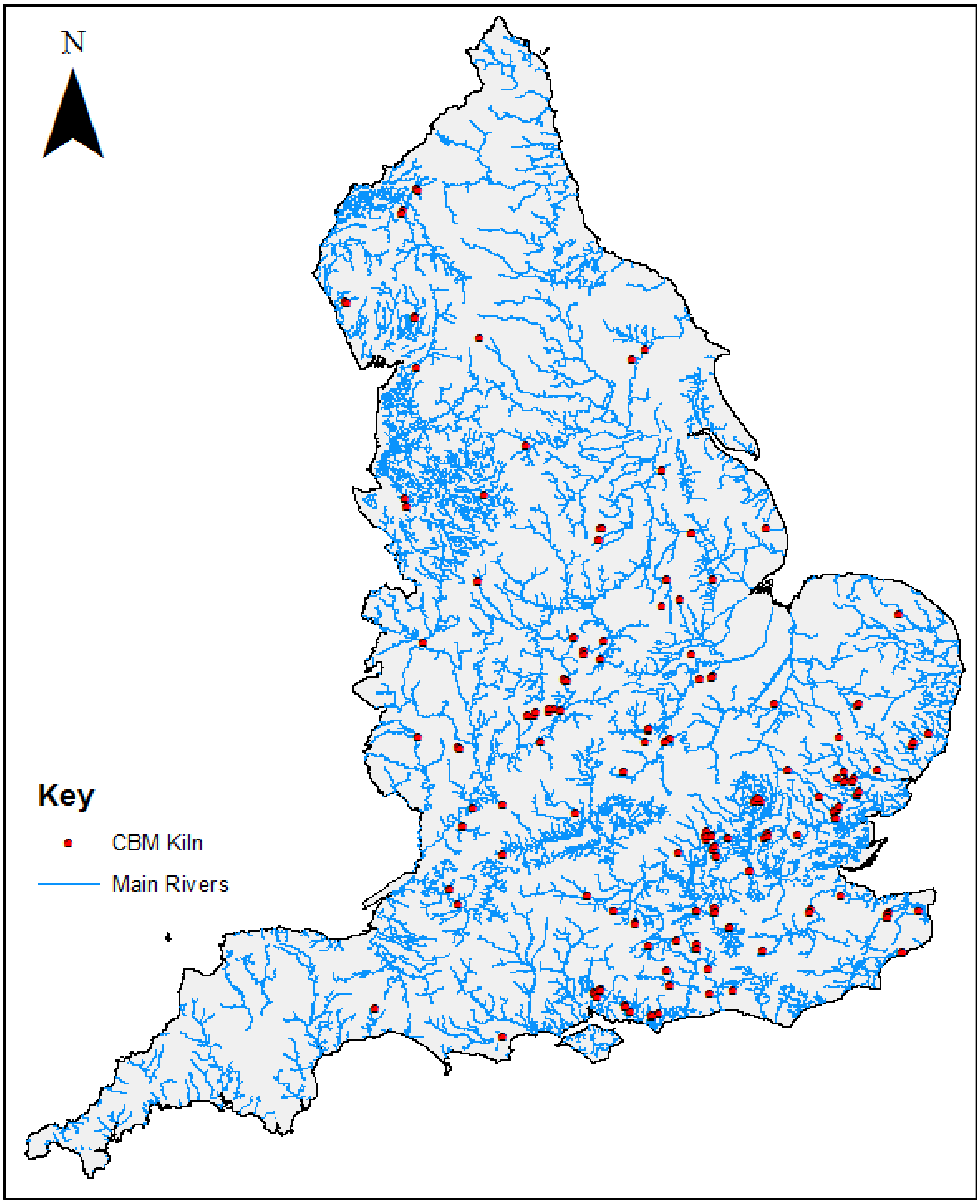

Figure 5. 19: Roman CBM kiln sites in England mapped against the Environment Agency's Main Rivers *Dataset.*

5.4.2.5. Kiln Sites and Villas

Finally, the proximity of kiln sites to known villa sites can be analysed (Fig. 5.20). For this analysis the *Rural Settlement of Roman Britain* villa dataset is used; of course it must be acknowledged that any attempt to catalogue "Roman villas" must make a number of assumptions regarding what characteristics are used to identify a villa.[458]

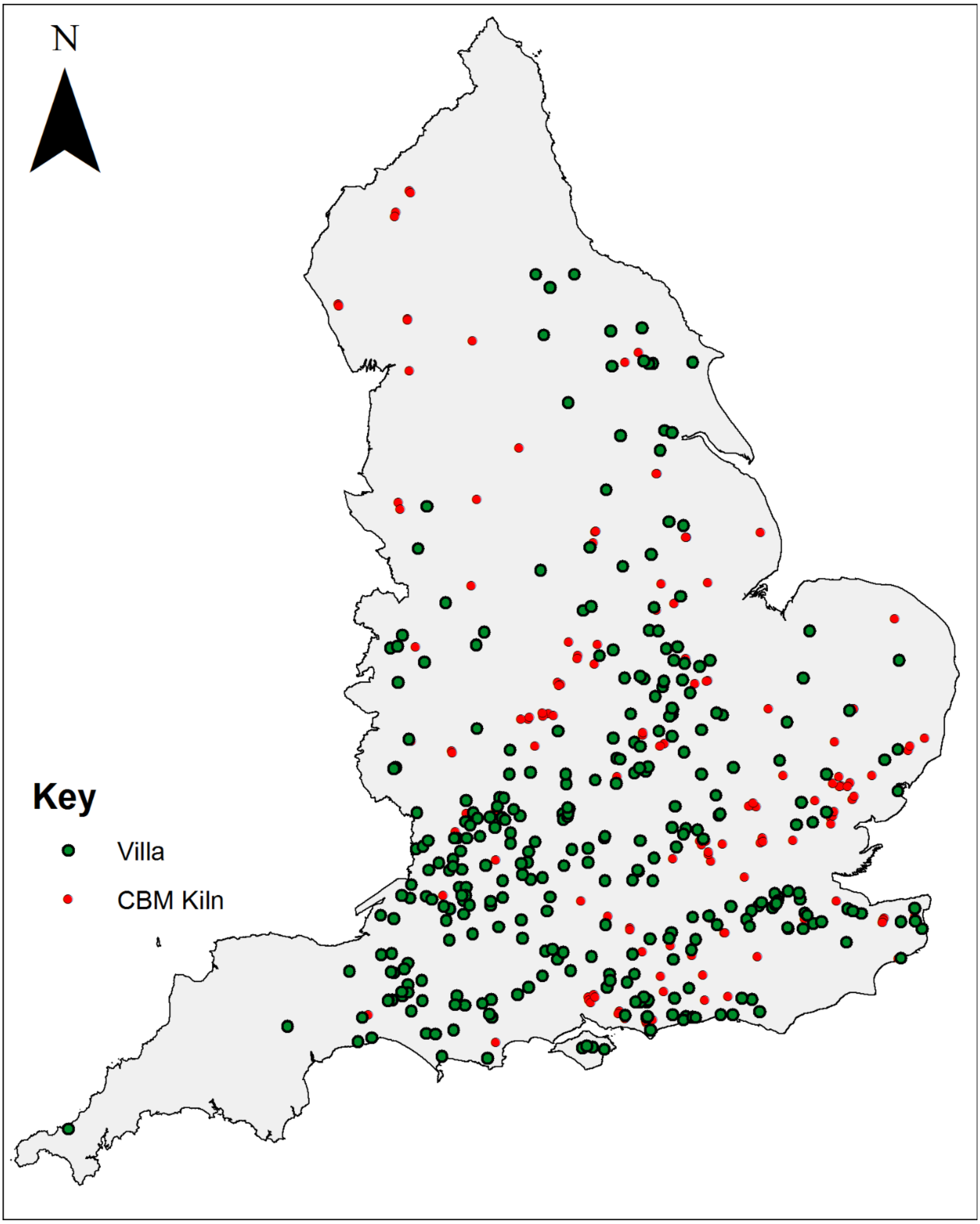

Figure 5. 20: Roman CBM kiln sites in England mapped against villas, as catalogued by the Rural Settlement of Roman *Britain Project.*

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[458] Dataset: URL = https://doi.org/10.5284/1030449 (Accessed 6/12/17); Smith *et al.* (2016).

The average Euclidean distance between any point in England and its nearest villa was calculated, coming out as 23.23 km, with a standard deviation of 24.8 km. The average distance between kiln sites and their nearest villa was 14.2 km, with a standard deviation of 19.4 km. The fact that the standard deviation is higher than the mean for the distance between kilns and villas is down to the absence of villa sites recorded in some parts of the country, particularly in the North West. The nine kiln sites in Cumbria are the nine furthest from a villa, all between 75 km and 110 km from their nearest. If these nine kiln sites are removed from the analysis, the mean distance between kiln sites and their nearest villa becomes 9.9 km, with a standard deviation of 7.7 km, and a range of 76 m up to 43 km. This finding reinforces the suggestion of a possible link between some tile kiln sites and higher status rural settlement, discussed further in Chapter 7.1.3.

5.5. Insight From Material Analysis

Having looked at the archaeological evidence surrounding the production of building materials, we now turn to the primary study of the collected building material assemblage, including the archaeometric analyses carried out in Chapter 4, to examine what these can add to this picture.

5.5.1. Stone Building Material Sources

The major quarry regions of later periods, with possible links to the Roman material, are displayed in Fig. 5.21. The stone assemblage from Roman Dorchester is interesting in particular for the dominance of roofing material over walling material in the excavated sample. This might reflect a low incidence of stone walling used in the town, perhaps on account of the difficulty of acquiring stone given Dorchester's distance from any suitable sources. Alternatively, or additionally, walling stone is more apt for re-use than roofing stone, resulting in higher rates of spoliation of the former: roof tile is more fragile than walling stone, being thinner, and during the process of building decay and collapse it is more likely to get broken, whilst even if walling stone is damaged by a fall, losing a face or corner, being larger it might still be usable with some retouching. The possible biases against the collection of larger blocks of stone during excavation should also be borne in mind (*cf.* Chapter 4.2.2.). Thus we must always bear in mind the caveat that our assemblage is incomplete, fragmentary, and victim to highly selective spoliation, significantly skewing any patterns of use.

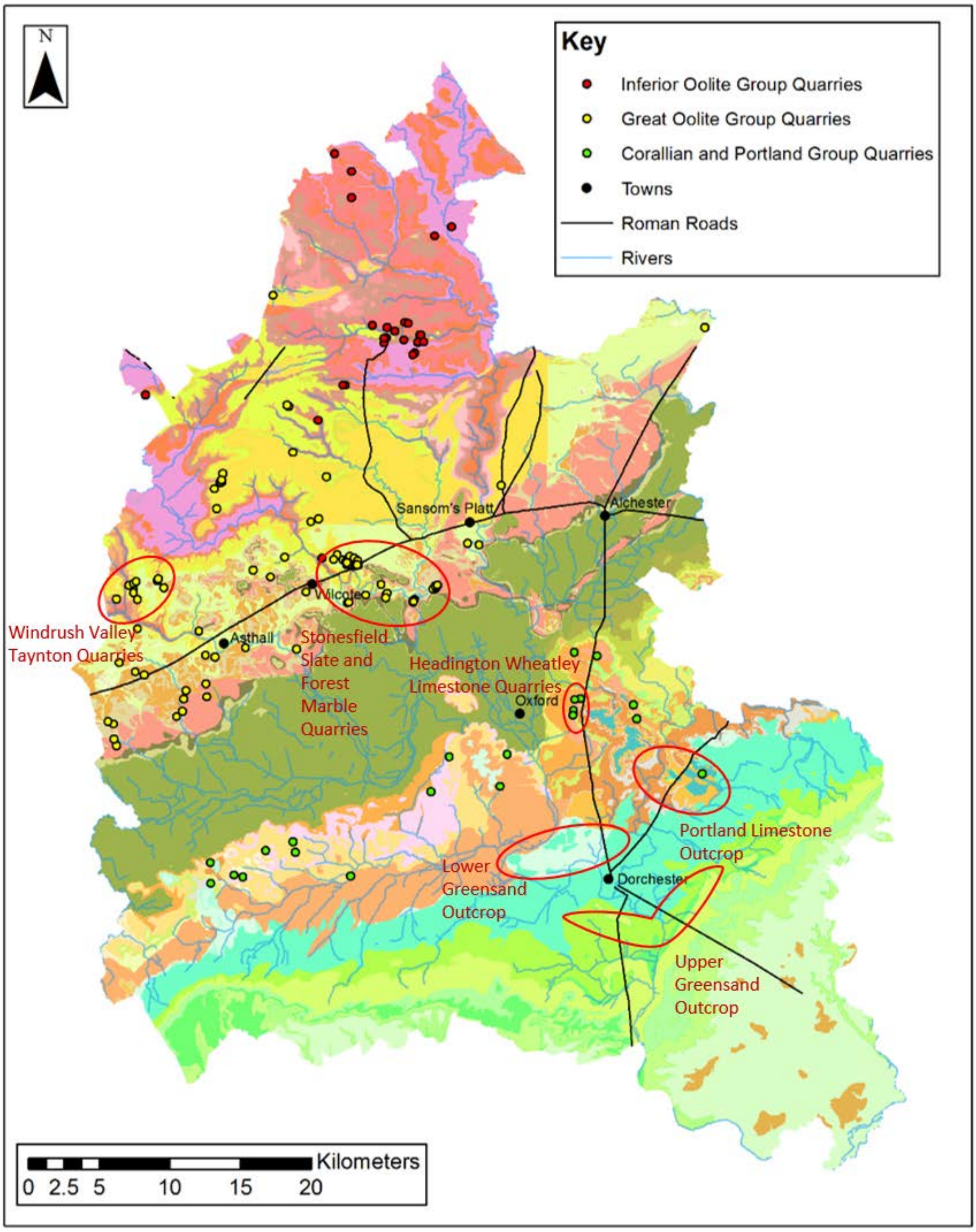

Figure 5. 21: Map of Oxfordshire with major building stone quarry regions with potential Roman exploitation highlighted, against a backdrop of the BritPits building stone quarries, Roman towns and roads, rivers, and the bedrock geology. Geological and quarry data © NERC 2017.

5.5.1.1. Walling Stone

What we can say about the few pieces of walling stone recovered (only one of which has been analysed in thin section, the rest simply in hand-specimen) was that they seem to largely reflect what might be deemed low quality building stones. Nodules of flint, irregular lumps of friable Lower Greensand and soft, degraded Upper Greensand, and the occasional piece of pale buff and white shelly limestone were the main walling materials found.

The flint may have been available within the small outcrops of chalk in the Wittenham Clumps, just the other side of the Thames from the town, or could have been found in much larger quantities in the White Chalk Formation, several kilometres south and east in the North Berkshire Downs and Chiltern Hills. Horsfield *et al.'s* research showed a cluster of villages making significant use of flint as a walling material in the vicinity of Lewknor.[459] The flint found in the trench has no signs of knapping in order to create shaped blocks with flat faces (as it is often seen used in the vernacular architecture of these villages in the south of the county). It is used as more-or-less entire nodules with the cortex still present, simply gathered and presumably laid as rubble walling with some kind of mortar, earth or lime, no longer apparent.

The Lower Greensand, as mentioned, outcrops just north of the village, along the north bank of the Thames between Burcot and Culham, but has only been noted as having been used in the Abbey walls in two or three places, the only instances observed in the modern village. The stone's loose, friable texture makes it a poor quality building stone, being too unconsolidated to work into well-shaped pieces, and having poor compressive strength and resistance to weathering. Horsfield *et al.* do not mention it amongst the building stones of the county, given its small area of outcrop, poor material qualities, and very limited use. Presumably however it could be used as aggregate in the centre of a mortared rubble. A few fragments have been found during the excavations of the Roman town (Sample 3095.1), suggesting it may have been used in this way, although lacking the original context or form, it is unclear whether these were used for walling, or, as has been suggested, as quern stones. It is this author's opinion that it would make poor quern

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[459] Horsfield *et al.* (2013) 122.

material given its highly friable nature. It is interesting however to note that the grinding grits used in the Oxford pottery industry mortaria are also thought to come from this formation, and these mortaria were produced by at least one of the kilns in the vicinity of Dorchester, at Allen's Pit, Berinsfield.[460] This opens the possibility of a coincident exploitation of the Lower Greensand for both the pottery industry and building stone trade.

The Upper Greensand outcrops due south of the village, just on the far side of the River Thames from Dorchester. On the whole, given its softness and susceptibility to weathering it would have made a relatively poor quality walling stone for any regular blockwork. However, its relative dominance of the stone used for boundary walls, and on occasion building walls, in the medieval and post-medieval buildings of the village shows it has been chosen for construction in more recent periods. Very few fragments have been found in the Roman assemblage from the village, and when found it is very soft and almost entirely disaggregated, falling to pieces. This might explain the lack of Upper Greensand in the excavated assemblage.

The limestone rubble pieces recovered were relatively fine, occasionally oolitic and often detrital, and with occasional bands of large shell fragments (5 – 20 mm in size). This stone appears to match well with limestone used in the Dorchester abbey walls, and it is suspected that this might be quarried from the Portland Formation outcrops northeast of the town. The small quantities recovered may reflect the relatively high quality of this stone for the production of squared blocks, and thus spoliation in the post-Roman period, or it would suggest that it was only used in small quantities, as it is in the modern village, because of the expense and difficulty of importing it. The vernacular architecture in Great

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[460] Harden (1936); Young (1977) 12 and 247; Booth (pers. comm. 3/12/17).

and Little Milton and Great and Little Haseley shows the use of this stone for producing squared blocks as well as use in rubble walling.

5.5.1.2. Roofing Stone

The far greater proportion of the Dorchester building stone assemblage appeared to be fragments of roof tile. This large tile-stone assemblage is interesting given the complete lack of stone roofing seen in the medieval and post-medieval buildings of the village, or indeed in any nearby villages. The lithology of these flaggy stones was variable, encompassing quartz arenites as well as limestone grainstones and packstones; within the latter both sparite and micrite cemented matrices were seen, as well as stones containing shell and oolith intraclasts. The two most easily identifiable lithologies present in the tile-stone assemblage were firstly significant quantities of stone identified as being from the Forest Marble Formation, and secondly a small quantity of stone identified as Stonesfield Slate.

Beginning with the former, a very significant proportion of the assemblage (the exact proportions, as stated, have not been calculated, as the assemblage is incomplete, spoliated, and fragmentary, making it unclear what any number calculated actually means) was characterised in hand specimen by a high concentration of shell fragments, oolites, a hard feel, and a speckled cream, blue, green, and grey colour. In thin section these stones were characterised by highly packed well-cemented coarse fossil and oolith intraclasts, with a variety of shell types visible including bivalves such as oysters and clams, and echinoid (sea urchin) spines. Fragments were as little as just one or two centimetres thick, resulting from narrow bedding plains, and making this an ideal stone for splitting for roof tile. Horsfield *et al.* note two major sites for quarrying the Forest Marble in Oxfordshire, notably around Filkins in the east of the county (where he particularly remarks on there being a flaggier facies suitable for roofing tile) and at East End quarry in

North Leigh.[461] Other sites for extraction may well have been exploited in the Romano-British period, and based on the insight gained above from the survey of historical quarries, we might suspect extraction sites in the river valleys of the Cherwell, Evenlode, and Windrush, where the stone would be exposed in the valley edges and transport onwards by water may have been possible. Additionally, Akeman Street is in places built on, and at times cuts into, outcrops of the stone, such as in its descent from the east down into the Evenlode valley where it cuts through layers of the Forest Marble. The proximity of the stone's outcrops to Alchester, and indeed also to Cirencester, as well as to the smaller roadside settlements at Wilcote, Asthall, and Quenington, might lead to the suggestion that these towns, or private individuals within them, may have had some involvement in the extraction of this stone, and its use in buildings in these towns (not firmly attested, but highly likely) might have inspired its use further afield.

Stonesfield Slate was identified in small quantities by hand-specimen for its grey colour and sandy texture with occasional strings of ooliths running through it. This stone is well-known for its popularity in the post-medieval period for roofing, particularly in Oxford and across the Cotswolds.[462] The outcrop of this flaggy tile-stone is in the surroundings of the town of Stonesfield, occurring at the base of the Taynton Stone Formation. It is worth noting that, whilst undoubtedly the tile-stones quarried at Stonesfield were historically very important, similar lithologies with almost identical characteristics can be found in various places in the Great Oolite, and without detailed petrological analysis of geological samples these stones may be indistinguishable. Roman use of suspected Stonesfield Slate has been noted before in excavation reports.[463]

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[461] Horsfield *et al.* (2013) 119.

[462] Horsfield *et al.* (2013) 118-9.

[463] E.g. Radford (1936) 44; Booth, Evans, and Hillier (2002) 253; Brodribb *et al.* (2005) 19.

The remaining, dominant portion of the assemblage cannot be attributed to a precise source formation. This is on account of a lack of good lithological descriptions of the great variation seen within formations and the similarities in descriptions between some lithologies. However, a range of possible sources can be suggested. The assemblage consisted of fine to moderately-fine oolitic and bioclastic grainstones and packstones, generally in the range of buff, cream, and white. Presumably these came from thinly bedded facies to allow for the production of tile-stones. Such descriptions could fit a number of geological outcrops. The Portland Limestone provides perhaps the geographically most proximate possibility, although the deposits of this stone are not noted in the literature for flaggy facies, nor, in Oxfordshire, highly oolitic stones, and nor are stone roofs seen in the locality of its outcrop today.[464] Similarly the lithological descriptions might match rocks in the Corallian coral rag or Wheatley stones, but again these outcrops are not known for their potential for producing tile-stones, with the nearest correlate being the Pusey Flags member, found some 20 km west towards Faringdon. Thus the remaining possible sources lie in the Great Oolite series of the Cotswolds, with the Cornbrash, Forest Marble, Taynton Stone, White Limestone, and Chipping Norton Limestone all possibly offering potential analogues. This statement, that the limestone roof tiles could have come from pretty much any limestone outcrop in the region, is not astounding or enlightening, but reflects the fact that a far greater degree of archaeological and geological research is needed if we are to begin to get to grips with the fine detail of the systems of building material production in the Roman world. It is certainly interesting to note that roof tile-stones, in the Forest Marble, Stonesfield Slate, and other possible lithologies, are travelling considerable distances, seemingly much further than the walling stone. This is a pattern noted in the recent architecture of the region by Horsfield *et al.*, surely reflecting both the greater specificity of characteristics required for roofing material

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[464] Horton *et al.* (1995) 74.

(thin, light, resistant to weathering, and strong), as well as the lightness characteristic facilitating easier transport.[465]

5.5.2. Stone Building Material Production

Evidence for specific details about tools and processes of production of this walling and roofing stone is fairly limited. None of the walling stone retains any clear traces of working, perhaps the result of selective spoliation of material with squared faces, more easily re-used.

The roofing material does offer up some original faces and clearly worked edges. For producing roofing material, stone splitting has been carried out in two ways in more-recent history. The first, which is noted as having been used in the Cotswolds for the production of tile-stone from the Forest Marble Formation, is the production of so-called "presents" – stones extracted near to the surface, and whilst still freshly quarried, and thus retaining the natural moisture or "quarry-sap," the stones are split by hand along their bedding planes.

The alternative, and a technique used most notably with the Stonesfield Slates in the medieval and post-medieval periods, is for the extraction of stone from slightly deeper quarries or adits in larger blocks, called "pendle." These would then be exposed to the winter frosts, which would naturally split the stone along its bedding plains. With the thinly bedded Stonesfield Slate this allowed much thinner and more regular tile-stones to be produced. Arkell comments that he thinks it unlikely that the Romans had discovered the frosting process, and that they would have relied on the "presents," exploiting outcrops closer to the surface, and using already split stone or working it physically with tools; what evidence he bases this assertion on is unclear, and a far larger assemblage of Roman tile-

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[465] Horsfield *et al.* (2013) 126.

stones of a lithology close to that of the Stonesfield Slate would need to be examined than was collected for this study in order to test this.[466]

The most obvious stone-working marks left on the Dorchester assemblage were the scalloped edges of some roof tile fragments, showing how they were shaped. This was presumably undertaken with the use of a slater's hammer, such as that found at Corbridge.[467] Whether this took place at the quarry site or at the building site is unclear: medieval and post-medieval analogy would suggest that most of the working would take place at the quarry site, with some finer working at the building site. We certainly seldom find large piles of 'débitage' near structures, suggesting most stone-working did take place elsewhere, or that the fragments were collected up, perhaps for recycling into mortar production or for use as aggregate in mortared rubble.

5.5.3. Ceramic Building Material Sources

Regarding exploring the sources of clay used, again few definite statements can be made. This work was handicapped by being at the forefront of the movement to use modern scientific approaches for characterising Roman CBM, meaning a lack of data against which to compare these results, and further difficulties come from the lack of kiln sites in the region and the scope of this thesis not permitting systematic geological raw material sampling. Nonetheless several broad observations can be made, as well as one that is rather more specific.

As was discussed in Chapter 4.2.1.3, we can make the general point that local production was certainly likely, with one or two dominant fabrics showing characteristics consistent with possibly having been made from the local Jurassic and Cretaceous bedrock clays. The

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[466] Arkell (1947) 129.

[467] No published reference to this could be found; *cf.* image at URL= http://www.english-heritage.org.uk/learn/story-of-england/romans/architecture/ (Accessed 15/11/17). *Cf.* Arkell (1948) 133 and Fig. 22 for a post-medieval comparison.

recognition of clays consistent with superficial, possibly alluvial origins, show that both bedrock and superficial clays need to be considered when exploring Roman CBM production. The variation seen in the assemblage, in both tile morphology, with differing flange shapes and sizes, and in differing fabrics, suggests that different sources were used throughout the timespan of construction in the settlement, in spite of its small size.

One particular fabric, Fabric 8, is worth discussing in more detail. On the basis of the petrographic and chemical results this fabric can be equated with so-called pink grog-tempered ware.[468] This is a pottery fabric in which certain 3rd- and 4th- century AD large storage jars, amongst other forms, are made.[469] The distribution of these vessels has been mapped, and a kiln site producing this material has been identified in the grounds of Stowe Park, Buckinghamshire.[470] It was already known that CBM was also produced in this fabric, and Mills has put together a distribution map of find sites, including as far west at Worcester and Alcester; Dorchester now becomes the most southerly known point in its distribution.[471] The coincidence of the heavy storage jar production and the CBM production, two heavy, bulky ceramics, is interesting, both for the physical comparability between the two products as well as for the possible insight this allows into the diversification of ceramic products at kilns and the relationship between agricultural centres (making the contents for filling the jars, hypothesised by Taylor to be honey), and building material production.[472] This is discussed further below (Chapter 6.1.3.; Chapter 7.3.) and elsewhere.[473]

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[468] Tomber and Dore (1998) 'PNK GT.'
[469] Booth and Green (1989).
[470] Booth (1999a); Northamptonshire Archaeology (2003); Taylor (2004) 61.
[471] Mills (2013a) 445 and 451.
[472] Taylor (2004) 65.
[473] Peveler (2016).

5.5.4. Ceramic Building Material Production

The analytical results also yield useful insight into the details about the material production process, as already set out in Chapter 4.2.1.3 – 5. The characteristics of the fabrics demonstrate relatively high quality, consistently formed and fired products. This reflects skilful production and considerable expertise: suitable clays were found, and consistent, very functional clay processing approaches were developed, suggestive of highly skilled, perhaps even ‘professional’ production, as opposed to *ad hoc*, ‘cottage industry’. Whilst we have not found them in the region, the kilns used must have been far more substantial than simple clamps, and were well-controlled in terms of temperature and firing atmosphere to yield highly consistent results and high quality products.

The dominant orange and red colours seen in the assemblage reflects a process of re-oxidation firing, and it could be considered whether this simply reflects the most basic firing procedure and the chemistry of the available clays, or whether it reflects a deliberate technological choice. Reduced black and grey coloured tiles were present, but were in a significant minority. The construction of a ceramic tiled roof surely represents an overt adoption of new, explicitly Roman technology, and it is conceivable that the orange colour of the roof was an integral aspect to it, as will be returned to in Chapter 7.

6. The Transportation of Building Materials

"I know not, in the whole range of language, terms sufficiently expressive to describe this infernal road… let me most seriously caution all travellers who may accidentally purpose to travel this terrible county, to avoid it as they would the devil, for a thousand to one they break their necks or their limbs by overthrows or breakings down. They will here be met by ruts, which I actually measured, four feet deep, and floating with mud, only from a wet summer… There are not merely opinions, but facts, for I actually passed three carts broken down in these eighteen miles of execrable memory." – Young (1771), on the road between Preston and Wigan.

The transport of building materials from their site of production to their site of use in the Roman period would have been an activity that required significant energy, even if that distance was relatively short. It is a key argument of this thesis that the movement of building material over any distance entailed significant effort and organisation. Even if the quarry for building stone, or kiln for tiles, was located anything over 50 or 100 metres from the building site, given the very large quantities of material needed, as demonstrated in Chapter 2.5.2, transport logistics would become a key consideration, and major cost.

The movement of goods in pre-industrial ages, and in the Roman period in particular, has attracted a great deal of attention from scholars. The connectivity of the ancient world, and particularly long-distance trade, has been explored using the remains of routeways (e.g. roads), associated infrastructure (e.g. harbour facilities), the remains of vehicles (particularly shipwrecks), and by taking commodities as proxies for those trade routes.[474]

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[474] E.g. Garnsey, Hopkins and Whittaker (1983); Parker (1992); Laurence (1998); (1999); Arnaud (2005); Morley (2007); Wilson, Schörle and Rice (2012).

A distinction has been suggested between what might be classed as light goods (such as pottery or glass vessels) and heavy goods (such as building materials or metal), with the latter requiring specialised technologies and infrastructure.[475] Consideration of unit volume needs to be added to this picture, in terms of both the volumes possibly being moved by 'wholesalers,' 'middlemen' or the like, and the volumes being purchased and moved by the end users. So, for example, whilst an individual might only buy one or two items of clothing or pottery at a time, representing a relatively light good in the marketplace, some traders might conceivably be moving very large quantities from production centres to markets, entailing the need for the specialised logistical considerations of heavy cargoes. Thus the distinction is perhaps somewhat false to draw. However, it is very clear that the quantities and weight of material needed for building projects far exceeds that of most 'everyday' commodities, from the producer, through any middlemen, right to the end-user. Indeed when these materials have been discussed in academic literature in the past transport considerations have been, in a way, nearly always the first concern, in that underlying the discussion of these commodities is often an assumption that they were locally sourced.[476] Chapter 5 has shown that this is not necessarily the case. With building materials, given their survival in the archaeological record, we are provided with an excellent avenue into researching the transport and trade of bulkier, larger volume commodities in the Roman world (in the absence of perishable alternatives such as timber). Extra attention therefore needs to be paid to the difficulties caused by such bulky cargoes and the increased effort and infrastructure needed to deal with them.

An interesting comparison can be made with the transport of food commodities, including amphorae and barrels of liquids such as wine and olive oil, and with the movement of

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[475] Burford (1960).

[476] Meijer and van Nijf (1992) 116.

grain, these being another type of material moved in large volumes and weights, and this will be explored further below (Chapter 6.1.3.).

First however the means and nature of distribution, an integral part of the chaîne opératoire for building material production and use, will be discussed, together with an assessment of the significant costs and logistical challenges involved in their movement, on account of the weight and bulk of material. In this chapter I will set out some of the considerations that need to be taken into account for our understanding of the movement of this material, in order to better comprehend the significance of this aspect of the 'industry' within the Roman economic and social landscape. A general background to Roman transport of goods is given first, before turning briefly to the nature of transport costs, and the complex circumstances which affect the time and ease of movement. The specific situation of Dorchester on Thames within its landscape of building material production is then considered, with the means of transportation, the distances, and the employed routeways analysed.

6.1. Roman Transport of Goods: Routeways, Vehicles, and Logistics

6.1.1. The General Background in the North Western Provinces

The transportation of goods is an implicit, if not always explicit, assumption of any discussion of Roman production and trade: trade was impossible without the movement of goods. The subject has of course been examined in detail, from Yeo's seminal 1946 work, through to work focusing specifically on building materials, such as Russell's work including articles and his 2013 book, chapter 4 of which specifically deals with the transport of stone.[477] The transport considerations for the construction of Hadrian's Wall were discussed by Kendal, although the operation of a military project, one on such a huge

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[477] Yeo (1946); Russell (2008); (2013a) 95-140; (2013b).

scale, was different from that of civilian construction.[478] Groenhuijzen and Verhagen have recently published the results of their wide-ranging study on transport on the Dutch *limes*, incorporating a palaeogeographic model, least-cost pathway analyses, and network analysis.[479]

Literary and papyrological evidence of course provides other sources of insight, the latter largely from Hellenistic and Roman Egypt, but of course the details of transport in that province will have had significant differences from transport in the different culture and climes of Britain.[480] Archaeological evidence for transport is our best source, with several key artefact types offering insights: physical remains of transport vehicles and infrastructure, depictions in art, and of course, the 'proxy evidence' gleaned from the discovery of goods at sites different from their place of production. In particular the deposition of archaeological organic remains in anaerobic sediments, often under water, protecting them from decay and other processes of destruction, give us on occasion superb preservation, and excellent insights particularly into timber vehicles.[481]

6.1.1.1. Maritime Movement

Maritime trade is understood to have been both the cheapest and fastest means of transporting goods or people over long distances. The importance of the Mediterranean as a medium of connectivity in the central parts of the Empire has been well discussed elsewhere, and important research is ongoing, for example with the Rome's Mediterranean Ports Project, led by the University of Southampton.[482] Literary, artistic, and archaeological evidence for the use of maritime transport for the movement of goods is particularly rich, including the substantial archaeological remains of harbours, wharfs,

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[478] Kendal (1996).

[479] Groenhuijzen and Verhagen (2015).

[480] *Cf.* Meijer and Nijf (1992); Adams (2002); (2007); Arnaud (2007) 325.

[481] Brunning (2010).

[482] Horden and Purcell (2000); Arnaud (2005); Keay (2012); (2016).

port infrastructure, and of course, shipwrecks. Hundreds of shipwrecks have been discovered across the Mediterranean, often with unperishable components of their cargoes still identifiable, the sum total demonstrating that maritime trade was booming in the Roman period.[483]

Literary Evidence

Undoubtedly the English Channel and North Seas were rather different in character for the Romans than the enclosed Mediterranean to which they were accustomed. Whilst strong winds, storms, and even cyclones, make sailing in the Mediterranean periodically dangerous, the unenclosed seas around Britain were affected by worse weather, more frequent storms pushing across the Atlantic, and the topography, conditions, and tides were not as well known or charted as those of the Mediterranean would have been by the 1st century AD. Nearly every Roman literary account discussing the waters of the English Channel and the North Sea makes reference to the dangers of sailing there: Caesar's army got into difficulties on his first crossing to Britain in 55 BC, and again a year later on his second crossing. This was followed by the wrecking of his anchored ships during the campaign that year, and he again faced difficulties on the return journey.[484] Similarly Germanicus' entire fleet was apparently wrecked in the North Sea near the mouth of the River Ems by a storm sometime in AD 16-19.[485] Cicero remarks on his delight at receiving a letter from his brother Quintus in September 54, whilst Quintus was in Britain serving with Caesar: he relates that he was "afraid of the ocean, and afraid of the coasts of the island."[486] The narrow straits certainly seem to have created an ideological barrier as well as a physical one: Suetonius Paulinus, in Tacitus' *Historia*, puts to Otho that British troops were unlikely to be able to reinforce Vitellius' bid for the throne, "kept back by the sea",

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[483] Parker (1992).

[484] Caesar *de Bello Gallico* IV.28; V.5; V.10; V.23.

[485] Tacitus *Ann.* II.23-24.

[486] Cicero *ad Quintum Fratrem* II.15.4.

despite the crossing taking less than a day.[487] The *Agricola* perhaps summarises this view in discussing Britain's waters: "nowhere has the sea more potent influence, with multiple tidal currents set in many directions."[488]

However, these accounts belie the fact that this must have been a busy shipping route in antiquity, with traffic moving around the coasts of France, Belgium, the Netherlands, and Britain, as well as crossing between Britain and the continental mainland. These routeways are known have been used since the Mesolithic, and evidence is rich in the middle and late Iron Ages of close contact between Britain and the European mainland.[489] From the Classical period literary evidence for this trade appears, with a reference in Caesar's *De Bello Gallico* one of our earliest sources for this subject: he refers to merchants trading between Gaul and Britain at the time of his first crossing, a detail repeated in Suetonius' *Julius*, where he notes Caesar's inquiries to these merchants for information on the harbours and navigations of the island, as a part of his planning for invasion.[490]

Archaeological and Artistic Evidence

Direct archaeological evidence for maritime trade around the coasts of Britain comes in the form of shipwrecks. The collection of essays edited by Du Plat Taylor and Cleere, resulting from a colloquium held in Canterbury in 1977, remains one of the best syntheses of the subject, although now somewhat out of date.[491] The *Navis* Projects, coordinated by the Römisch-Germanisches Zentralmuseum and the Museum für Antike Schiffahrt, both in Mainz, added further examples, brought together in an online database, up to 2002.[492] Since then the *Archaeological Atlas of the 2 Seas*, run between 2009 and 2012 by an international collaboration between British, Belgian, and French institutions, has further

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[487] Tacitus *Hist.* II.32.
[488] Tacitus *Agricola* X.6.
[489] Wilkes (2004); Garrow and Sturt (2011).
[490] Caesar *de Bello Gallico* IV.20-21; Suetonius *Julius* LVIII.1.
[491] Du Plat Taylor and Cleere (1978).
[492] URL = https://www2.rgzm.de/navis/home/frames.htm (Accessed 19/07/17); URL = https://www2.rgzm.de/Navis2/Home/Frames.htm (Accessed 19/07/17).

added to our picture of wrecks in the North Sea and English Channel in the Roman period.[493]

One of the most important wrecks for this research is that of the Blackfriars I boat, found next to Blackfriars Bridge in the bed of the River Thames in London. Discovered in 1962, and its sinking dated to c. AD 150, the boat measured c. 14 m long and 6.5 m wide, and was carvel-built in oak.[494] The ship was found with personal objects and its cargo still on board, putatively having sunk as the result of a collision with another vessel.[495] The cargo was a quantity of building stone identified as ragstone from the Hythe Beds of the Lower Greensand Formation outcropping in Kent, probably quarried in the vicinity of Maidstone.[496] The ship would most likely have picked up its cargo, estimated to be roughly 26 tonnes of stone, on the River Medway, and then travelled around the Hoo Peninsula into the Thames, using the incoming tide to proceed up river to London.[497] During this mid-2nd century AD period a great deal of construction work was being undertaken in London, and demand for stone, most often Kentish ragstone, would have been huge: Marsden estimates that the early 3rd-century city walls of London used c. 35,000 cubic metres of stone, roughly 45,000 tonnes, or, given the size of the Blackfriars I cargo, c. 1,750 journeys of ships from the quarries in the vicinity of Maidstone to London.[498] However, this ship was not just used for journeys on the tidal estuaries of the Medway and Thames: the hull planking showed borings created by shipworms of *Teredo* species and isopods of *Limnoria* species, both of which only live in far saltier water than these estuarine environments, demonstrating that the Blackfriars I ship had spent significant time undertaking maritime journeys.[499] Marsden suggests that, on account of an unfinished

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[493] URL = www.a2s-geoportal.eu (Accessed 20/07/17).
[494] Marsden (1967); (1994) 33-95; McGrail (1991); (1995).
[495] Marsden (1994) 91.
[496] Marsden (1994) 80.
[497] Marsden (1994) 80-81.
[498] Marsden (1980) 126-7; (1994) 83.
[499] Marsden (1994) 86.

millstone found aboard, provenanced to a millstone grit outcrop near Namur in Belgium, and through which the River Meuse flows, the ship may have picked up this object during a channel crossing.[500]

Another important wreck for showing the transport of heavy materials by sea is that known as the Ploumanac'h wreck, found c. five miles off the Côte d'Armor in Brittany. This wreck is notable for its cargo of 271 lead ingots (22 tonnes), 14 of which were incised with the names of the British *civitates* of the Brigantes and the Iceni.[501] The ship presumably represents the export of British lead, perhaps to Bordeaux, and given the dating of the wreck to the 4th century, the find is notable for demonstrating the continuity of Atlantic maritime trade to and from Britain in this later period.[502]

Archaeological remains of harbour facilities provides further evidence for maritime trade, and this has been well-summarised by others.[503] Tidal reaches of the Thames in London, the Usk at Caerleon, and the Dee at Chester all provide evidence of Roman harbour facilities in Britain.[504] London presents the most detailed picture, with significant developer-funded archaeology along Lower Thames Street (which runs roughly on the line of the Roman water-front) between Old Billingsgate Market and Cannon Street Station, and in Southwark, have shown the extensive dock facilities which existed. These include the massive timber-framed quay with clay, earth, and rubble infilling at Pudding Lane and Billingsgate, and the jetty and warehouse at the Courage Brewery Site in Southwark.[505] Morris' claim that "Londinium was... probably handling more tonnage than any other port

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[500] Marsden (1994) 85 and Fig. 77.
[501] L'Hour (1987) 120.
[502] L'Hour (1987) 130-131.
[503] Cleere (1978); Milne and Hobley (1981); Jones (2009); (2012).
[504] Jones (2012) 78-82.
[505] Bateman and Milne (1983); Milne (1985); Brigham and Hillam (1990); Brigahm (1998); Rogers (2011).

in Roman Europe" has rightly been dismissed, but there was certainly considerable activity between the 1st and 4th centuries.[506]

Artistic depictions of boats provide further clues to the structure, style, and frequency of maritime shipping in the North Sea and English Channel. Of particular note are the votive monuments to the goddess Nehalennia, found at Colijnsplaat and Domburg in Zeeland, and dating to the 2nd and 3rd centuries AD. In line with the goddess' role as a protector of sailors and trade, she is often depicted standing next to a ship's prow, the offerings dedicated by merchants crossing the channel, praying for a safe journey.[507]

With regard to the speed of maritime transport, this will have been highly dependent on the specific conditions faced on the journey, as discussed further below (Chapter 6.1.2). Marsden calculated for the Blackfriars I ship that a speed of c. 7 knots might be the usual maximum, although that 9 – 10 knots might be possible with the right circumstances.[508] A combination of archaeological evidence for Roman ship construction with historical accounts of sailing times allowed the Stanford ORBIS project to accurately model the durations of sea journeys around the Roman world.[509]

Proxy Evidence from Finds

Besides the direct evidence of maritime trade shown by shipwrecks and harbour facilities, the patterns of occurrence of certain goods, combined with a knowledge of their origins, allows maritime trade in these seas to be identified by proxy. There were significant quantities of certain goods making the journey from the continent to Britain, the most visible being ceramics, including amphorae such as Gauloise 4 and Dressel 20, and finewares including *terra sigillata* from Central and Southern Gaul.[510]

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[506] Morris (1982) 162; Jones (2012) 82.
[507] Hondius-Crone (1955); Stuart and Bogaers (2001).
[508] Marsden (1994) 89 and Appendix 5.
[509] Scheidel, Meeks, and Weiland (2012) 12-16.
[510] Peacock (1971); (1978).

A maritime trade in stone also existed, as has been recognised principally from the study of quern stones, with the identification of lavas from the Eifel region of Germany and the above mentioned millstone grit from Namur entering into the British market.[511] These are not building stones, and no correlation between the distribution and functioning of the trade in these two uses of stone is suggested, but the close analyses to which quern and mill-stones have been subjected shows the potential insights which might be gained from the same approach to building stones.

Besides the trade in stones suited for use as grindstones, fine limestones for carving (gravestones and architectural ornament, for example) also made their way to Britain from the European mainland. These included Calcaire Grossier, quarried in the Oise Valley in north east France, found used at sites such as Fishbourne, a journey of c. 350 km, and at Richborough, a journey of c. 420 km.[512]

Significant quantities of 'marble,' used principally for wall veneer and *opus sectile*, are also found in Britain. They were used particularly in urban contexts, for example at Colchester, London, Canterbury, Lincoln, and in the palatial villa at Fishbourne. Stone types found in Britain include white marbles from Luna, Prokonnesos, and Dokimeion, as well as Phrygian, Carystian, Pouillenay rose from the Cote d'Or, and Campan vert from the French foothills of the Pyrenees, amongst others, all of which had to travel by sea to reach Britain.[513]

CBM was also transported by sea. Some of the roof tiles used in a bathhouse built by the *Classis Britannica* at Beauport Park, East Sussex, can be identified through stamp and fabric analysis as having been made at the fleet's base in Boulogne, France, showing

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[511] Peacock (1980); King (1986); Shaffrey (2006); Gluhak and Hofmeister (2011); Reniere *et al.* (2016).
[512] Hayward (2009) 88.
[513] Cunliffe (1971); Pritchard (1986); Peacock and Williams (1995) 354-355.

military redistribution using maritime transport.[514] Military production and redistribution are often assumed to operate differently and somewhat independently of civilian market functioning. However, redistribution by sea of CBM as part of normal civilian market function has also been identified in the trade of distinctive calcareous-fabric *tegulae* around the south coast of Britain, appearing in London, Essex, Kent, on the Isle of Wight, and at Winchester, amongst other places.[515]

6.1.1.2. Riverine Movement

Rivers are also known to have been widely used when available, from the importance of the Tiber, for bringing goods both downriver from the productive inland plains of Etruria and Latium, and also upriver (or up-canal) from Ostia and Portus to the port of Rome itself, to the extensive use of the major rivers of France and Germany for connecting the north-western provinces with the markets and products of the Mediterranean.[516] Evidence for riverine transport is perhaps less frequent than maritime, largely on account of the often poorer preservation of archaeological material on riverbeds.

Reconstructing the exact courses and navigability of rivers in the Roman period is a very difficult task. Firstly, rivers "evolve," changing their own courses over time through processes such as migration, growth, and retraction of meanders, affected by factors such as climate, flooding, bank erosion, channel instability, sediment load, vegetation, and debris.[517] In Britain movement of river courses by as much as 3 metres per year has been recorded.[518] Secondly, rivers are altered by anthropogenic factors. Some are plain: the construction of locks and cuts, the dredging of channels, or the construction of weirs or mills might all, in a very short space of time, entirely transform whether a river was

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[514] Peacock (1977a); Brodribb (1979).
[515] Betts and Foot (1994).
[516] Greene (1986) 30; Graham (2006) on the brick industry in the Tiber valley.
[517] Hooke (1984); (2007).
[518] Hooke (2007) 292.

navigable or not. Other processes are rather more subtle: the cutting down of woodland or the intensification of ploughing might modify rates of surface run-off, siltation rates, and bank stability, influencing characteristics such as channel depth and speed of flow.[519] In spite of these difficulties, we know that rivers formed an integral part of the transport systems of the Roman world.

Literary Evidence

Roman law instigated the principle, widely copied in many later law codes, of the right to use inland waterways.[520] Roman law distinguished between rivers and streams on the basis of size, between perennial and torrential (i.e. seasonal), and between public and private: "Cassius defines a public river to be one which flows uninterruptedly. This opinion of Cassius, which is approved by Celsus, seems to be plausible."[521] The Digest notes that the Praetor prohibits anything which "deterior statio et navigatio fiat:" "harms the landing of goods or navigation on the river."[522] These laws, cited by Justinian as having originated in Ulpian's *ad Edictum* LXVIII, thus dating from at least the early third century, show a careful consideration of the necessity and difficulties of moving by river.[523] That navigable and non-navigable rivers exist is an implicit point of these laws, although sadly no further details are given on this distinction, one which is often difficult to make, and which is discussed more below.[524]

Beyond the legal evidence, Strabo notably praises the rivers of Gaul for their navigability and useful distribution, allowing easy travel across the region, and he describes the journey to Britain via the Rhône, Saône, Doubs, and Seine.[525] Tacitus' account of the planned

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[519] Kondolf *et al.* (2002).
[520] Justinian *Pandectae* 43.12.1.1. after Ulpian *ad Edictum* 68. Cf. for example *Magna Carta* Clause 33: "All fish-weirs shall be removed from the Thames, the Medway, and throughout the whole of England, except on the sea coast."
[521] Justinian *Pandectae* 43.12.1.2; 43.12.1.3.
[522] Justinian *Pandectae* 43.12.1.12-15.
[523] Justinian *Pandectae* 43.14.1., after Ulpian *ad Edictum* 68.
[524] Justinian *Pandectae* 43.12.1.12., after Ulpian *ad Edictum* 68.
[525] Strabo *Geographica* IV.1.2 and IV.1.14.

construction of a canal between the Saône and Moselle, and Pliny's letter to Trajan discussing another possible canal project, show the Roman desire to artificially expand inland water-borne transport networks.[526]

Archaeological and Artistic Evidence

Again shipwrecks provide a valuable source of direct archaeological evidence for the use of rivers for trade. With regards to the north western part of the Empire the Rhine furnishes the largest number of examples. Several wrecks have been discovered at the Roman military camp at Zwammerdam (Nigrum Pullum), with evidence of 6 vessels found, including three dug-out boats (Zwammerdam 1, 3, and 5), three flat-bottomed barges of clinker construction (Zwammerdam 2, 4, and 6), and planks from one or more further wrecks using carvel-construction.[527] The wrecks are dated roughly to the 2nd to early third century. Zwammerdam 4 is noted as having had a cargo containing "Ziegelgrus" – crushed brick, presumably for construction purposes as aggregate or for the production of *opus signinum*.[528] Several of these boats had broad, gently sloping 'swim heads,' which would have allowed the easy transfer of goods, or even the loading of wagons or cattle directly onto the boat, without significant harbour infrastructure, simply by running the boat aground on a bank.

The Rhône River provides a number of wrecks indicating the importance of riverine trade. Of particular importance is the Arles-Rhône 3 wreck, a 31 m long, 3 m wide flat-bottomed barge found in the river at Arles, and dating to the second half of the 1st century AD.[529] This wreck was found to contain a cargo of roughly shaped limestone blocks, quarried c.

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[526] Tacitus *Ann.* XIII.53.2-4; Pliny *Letters* X.41.1-2.

[527] De Weerd (1978) 15.

[528] De Weerd (1977).

[529] Djaoui, Greck, and Marlier (2011) 142-6; Marlier (2014).

15 km upriver at Tarascon, presumably being brought for use at Arles or another site downstream.[530]

The shipwreck known as New Guy's House boat, found close to the south end of London Bridge, provides another interesting piece of evidence.[531] Abandoned at the end of the 2nd c. AD, it was built entirely of oak using carvel construction; the boat measured c. 16 m long, c. 4.25 m across the beam, and only c. 1 m deep amidships. On account of this shallow depth it is presumed to have been a river barge.[532] The boat seems to have had a hold for carrying cargo, estimated to be up to c. 7 tonnes, but with its vertical sides it would have needed to be loaded at a quay: this implies the existence of river quays further up the Thames, perhaps even towards the study area of this thesis.[533]

Besides wrecks, other archaeological evidence for the use of rivers for transport lies in the find of quays and other harbour facilities on waterways. The examples given above of the harbour facilities at London, Chester, and Caerleon on tidal reaches of the Thames, Dee, and Usk respectively, were presumably all used for riverine trade as well, and to these can be added quays found at Gloucester on the Severn and on the Witham at Lincoln.[534]

Artistic representations from France and Germany further enrich our picture. Ellmers collects many excellent examples.[535] These include the "wine boat" depicted on the funerary monument found at Nijmegen, now in the Rheinisches Landesmuseum in Trier, and dated to c. AD 220, which shows a ship with animal-head decorations, banks of oars, and four large wine barrels on board thought to be being transported down the Mosel. Other depictions of riverine transport include the relief now in the Musee Lapidaire, Avignon, showing a barge loaded with two wine barrels being towed, presumably

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[530] Marlier (2014); Bromblet *et al.* (2014).
[531] Marsden (1994) 97.
[532] Marsden (1994) 102.
[533] De Weerd (1988) 205; Marsden (1994) 104.
[534] Jones (2012) 80-81.
[535] Ellmers (1978) 8.

upstream on the Rhône, by three men, with a fourth helming the boat. Two tombstone fragments from Mainz, dated to c. AD 200, show, respectively, porters rolling barrels aboard a boat and others carrying sacks ashore.[536]

It is often taken as read that, if a river was present, it would have been used. However, our interpretation of them must be cautious: as Russell notes, we must avoid thinking of these geographical features simply as “blue lines on maps.”[537] As will be discussed in more detail below, a river’s course and character may have changed significantly since, and even during, the Roman period, and indeed that character is complex, dependent on seasonal, weather, geological, biological, and human factors. We know that the Romans altered the course and character of some rivers, including the construction of flash locks on the upper reaches of the Tiber, as described by Pliny the Elder, and of course through the construction of canals, including the Car and Fosse Dykes in eastern Britain.[538]

All of these aspects again make it difficult to offer generalised speeds of travel, with specific conditions on any rivers significantly altering the distances that it was possible to travel in a day. The Stanford ORBIS project is again useful, noting these difficulties, which are compounded by an absence of ancient references to travel by river.[539] They note that the major determining factor is the speed of the river flow, being the main form of propulsion for most downriver travel, and so offer a figure of around 65 km per day on many of Europe’s rivers, deviating slightly above or below this (up to 75 km and down to 45 km) on some rivers; they use a figure of 15 km per day for most upriver travel, which must have either been propelled by oars or poles, or perhaps more commonly made use of mules or

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[536] Ellmers (1978) 12-14.

[537] Russell (2016).

[538] Pliny *Historia Naturalis* III.5.53; Keay (2012); Smith (1977).

[539] URL = http://orbis.stanford.edu/#riverstime (Accessed 14/08/17).

other draught animals for towing, something evidenced by Strabo's description of travel on a canal alongside the Appian Way.[540]

Proxy Evidence from Finds

Proxy evidence again enriches our understanding, and evidence can be found across north-western Europe of the use of rivers for the distribution of goods, including building material. The best studied example is the corridor formed by the Rhône, Saône, Moselle, and Rhine, providing transport links by river almost unbroken between the Mediterranean and the North Sea (and Tacitus tells us that there were even plans to construct a canal between the Saône and Moselle, to make the route complete).[541] The distribution of amphorae, such as the wine-container Gauloise 4 originating in southern Gaul, up the Rhône into the Rhine valley, and seen at the cities of Mainz, Bonn, Cologne, Xanten, and Nijmegen, and in Britain, is one such example.[542] Jones and Mattingly cite another in the distribution of certain stamped Dressel 20 amphorae up the Rhône, Saône, Rhine, and into Britain, showing that these vessels and their olive oil, despite originating in south western, Atlantic-facing Baetica, came by river through Europe as opposed to having been brought by the Atlantic route.[543] Southern Gaulish *terra sigillata* produced at La Graufesenque, near modern Millau, is produced on the banks of the River Tarn: this river flows into the Garonne, and out into the Bay of Biscay at Bordeaux, from where it could be transported by sea to Britain, or alternatively it could also make the route via the Rhône/Rhine axis.

Of particular interest for this study, looking at Britain, is the transport of products of the Oxford pottery industry.[544] Whilst these represent a very different cargo to building materials, the transport of oxidised colour coated finewares from kiln sites in the vicinity

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[540] URL = http://orbis.stanford.edu/#riverstime (Accessed 14/08/17); Strabo *Geographica* V.3.6.
[541] E.g. Peacock (1978); Jones and Mattingly (1990) 196; Tacitus *Annales* 13.53.
[542] Peacock (1977b); (1978); Peacock and Williams (1991); Laubenheimer (2001); (2004).
[543] Jones and Mattingly (1990) 196-7.
[544] Young (1977).

of Oxford and Dorchester on Thames down to London is seen in significant quantities in the third and fourth centuries, perhaps as a replacement for Gaulish *terra sigillata*, whose forms the Oxford ware often mimics.[545] This journey is presumably undertaken by river, and perhaps goes some way to explaining the success of that industry and wide-distribution through southern England. The ware even dominates in the Severn Valley, but whether this demonstrates upstream movement of the pottery along the Thames, and how far it could reach, is unclear.[546]

In terms of building material, stones quarried and used in north east France, Belgium, and North West Germany have been well studied in the last few years, and it is clear that these often travelled by river.[547] The work of Ruppiene on decorative stones used for building facades at Xanten is particularly insightful, showing the import, presumably largely via the Moselle and Rhine, of stone from numerous quarries in Germany and France, as well as from the Mediterranean up the Rhône and down the Rhine.[548] Hayward discusses the movement of Inferior Oolites, including Athelstan Oolite ("Bath Stone") and Pea Grit (including "Painswick Stone") from Somerset and Gloucestershire, to sites such as Silchester, London, and Colchester, and suggests the transport of the stone by land to Lechlade and movement from there by the Thames: Lechlade certainly represents a high point of navigation on the river in the post-medieval period, but whether it was reachable in the Roman period is unclear, and will be discussed further below.[549]

6.1.1.3. Road Movement

The use of roads as a means for transport is plain: the relative costliness of road transport, compared to riverine and maritime has in the past perhaps deterred more detailed

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[545] Marsden (1994) 107; Young (1977) 238-239.
[546] Young (1977) 13, 234-5, 238; Booth *et al.* (2007) 317.
[547] *Cf.* papers given at "Roman Ornamental Stones in North-Western Europe" conference, Tongeren 2016.
[548] Ruppiene (2015) Fig. 3.
[549] Hayward (2009) 86.

consideration of the role of over-land movement of goods, particularly heavy ones. The vast majority of the Roman Empire was not accessible by river or sea, and thus it seems evident that many journeys, and movement of goods, undertaken in the Roman world must have been by land, either by human hands, or by animal, simply in packs or through animal traction of vehicles.

Our understanding of the vehicles, goods, and scales of movement along the Roman road network is more limited than that of maritime or riverine, predominantly on account of the issue of preservation of primary evidence of vehicles. Roads themselves have been relatively well-studied around the Empire, from Laurence's studies of Italy, to Margary's surveys of Romano-British roads, followed up most recently by Davies.[550] With regards to road traffic, and the act of transportation being conducted along roads, there is rather less work. Quilici and Raepsaet piece together broad surveys of the topic, concentrating on Italian evidence primarily, whilst particular aspects have been examined over the last century in papers by Yeo, Burford, Mitchell, and Adams, amongst others.[551]

Literary Evidence

Again, literary evidence from the Roman period for the experience of travelling or moving goods by road is relatively rare, but occasional references are seen, particularly with regard to the legal definitions of roads and, as with rivers, the rights of use. The *Twelve Tables*, the fifth-century BC law code of Rome, already set out that in order to be classed as a road, a *via*, the passage must be c. 8 feet wide on straights, and c. 16 feet wide around bends.[552] Laurence collects further evidence, citing Hyginus discussing the width of many roads built in Italy in the late 2nd and 1st centuries BC being c. 12 feet wide, permitting two vehicles to pass comfortably.[553] Ways narrower than this, but over 4 feet wide, were classed as *acti*

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[550] Laurence (1999); Margary (1973); Davies (2002).
[551] Yeo (1946); Burford (1960); Mitchell (1976); Adams (2007); Quilici (2009); Raepsaet (2009).
[552] *Twelve Tables* 7; Justinian *Pandectae* 8.3.8.
[553] Laurence (1999) 59; Hyginus *Poeticon Astronomicon* 134.

as opposed to *viae*, still allowing the passage of a vehicle.[554] Siculus Flaccus makes the distinction between three main types of road, with varying responsibilities for construction and maintenance, and of rights of access.[555] *Viae publicae* were built and maintained by the state, forming the major routeways across the landscape, whilst local roads, *viae vicinales*, were maintained by local communities and often linked the major roads.[556] *Viae privatae* were built and maintained by the local landowners, and were not necessarily publicly accessible.[557]

Cicero in his letter to Quintus of 28th September 54 BC discusses the road being improved at the latter's estate at Laterium:

"viam perspexi; quae mihi ita placuit ut opus publicum videretur esse, praeter CL passus… eo loco pulvis non glarea iniecta est (et mutabitur), et ea viae pars valde acclivis est."

"I examined the road, which appeared to me to be so good as to seem almost like a high road, except a hundred and fifty paces… There they had put down dust, not gravel (this shall be changed), and that part of the road is a very steep incline."[558]

Thus the quality of the surface, as well as width and incline, seem to be key aspects defining the quality of a road to the Romans.

Laws on the use of roads went beyond simply the right of use: the *Pandectae* reveal that 'servitudes' (conditions between a subordinate and dominant estate) could be added to private roads, limiting the weight of loads that could be brought along them, or the draught animals which could be used on them.[559] Famously wheeled traffic was banned from entering Rome during the day, as was inscribed in section two of the Latin text on

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[554] Justinian *Pandectae* 8.3.7; Varro *Lingua Latina* 5.22.
[555] Siculus Flaccus 146L.
[556] Siculus Flaccus 146L.
[557] Laurence (1999) 61-62; Siculus Flaccus 146L; Ulpian *Digesta* 43.8.21.
[558] Cicero *ad Quintum Fratrem* 3.1.2.
[559] Justinian *Pandectae* 8.1.4.

the *Tabula Heracleensis*, the *lex Iulia municipalis* (with the possibility that, the inscribed law having been found in a town on the southern coast of Lucania on the Gulf of Taranto, the law might have been applied to other urban sites).[560] Suetonius tells us that Claudius brought in legislation, "that travellers should not pass through the towns of Italy except on foot, or in a chair or litter," and the *Historia Augusta* tells us that first Hadrian and then Marcus Aurelius reinforced these laws, Hadrian forbidding entry into Rome of "vehicula cum ingentibus sarcinis:" "vehicles with huge weights," and Marcus Aurelius forbade the riding of a horse or in a vehicle, in all cities.[561] Van Tilburg suggests that such laws would, like that inscribed on the *Tabula Heracleensis*, only apply during daylight hours, and of course they may not have been enforced in all parts of the Empire.[562]

An important written source for travel on the roads of Britain is the Antonine Itinerary.[563] The purpose or significance of the routes listed in the itinerary is not entirely apparent, with its jumbled order, repeating sections, and omissions, all ruling out the text being a military itinerary or a manual for the *Cursus Publicus*.[564] Errors in measurements and corruption in copying create complicated problems for identifying locations, and a number of the places mentioned cannot be securely tied with known sites.[565] The conclusion of Rivet and Jackson that the *itinera* represent a collection of journeys, planned or real, by various people at various times and collected by an imperial official, seems sensible.[566]

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[560] Hardy (1914) 72; Crawford and Nicolet (1996).
[561] Suetonius *Claudius* 25.2; *Historia Augusta* Hadrian 22.6; *H.A.* Marcus Aurelius 23.8.
[562] Van Tilburg (2007) 134.
[563] *Itinerarium Provinciarum Antonini Augusti* 463.3-486.17, ed. Cuntz (1929); Rivet and Jackson (1970).
[564] Rivet and Jackson (1970) 36.
[565] Rivet and Jackson (1970) 37, 62-65.
[566] Rivet and Jackson (1970) 67.

Archaeological and Artistic Evidence

Travel along the roads with cargoes must have involved either the use of a pack animal, or the use of a vehicle pulled by animals, and we will consider the details of these, plus the question of human porterage, below (Chapter 6.1.2.).

Clearly one of the most visible and enduring pieces of evidence for the use of roads for transport is the roads themselves. The major Roman roads of the Empire are often fossilised as modern routes, or can still be seen through patterns of tracks and field boundaries, carving more-or-less straight lines across the landscape, and connecting the major Roman towns. Occasionally the *agger*, or raised embankment, on which main roads were sometimes constructed can still be seen, for example the section of Akeman Street where it passes through the park of Blenheim Palace in Oxfordshire. As noted the evidence from Britain has been well catalogued by Margary, and the discussion developed recently by Davies.[567]

Just as with rivers, to borrow the turn of phrase from Russell, we must not simply see roads as "black lines on maps."[568] Roads, as highlighted by the literary evidence above, could be of highly variable quality, in a spectrum from the *viae publicae* with layers of foundations, a raised *agger*, and a solid stone surface cambered for drainage, down to rough tracks, or simply cleared paths. Even the best-built roads were susceptible to wear and damage, as can be seen by the heavily rutted surfaces of some sections of Roman road, for example on the Via Trajana at Monopoli, near Brindisi.[569] *CIL* IX 6075, dating to AD 123/4, tells us that at that time the Via Appia was impassable (perhaps allowed to happen because of the opening of the Via Trajana), and that repairing 15.75 miles involved a payment of 1,470,000 sesterces from Hadrian, added to the 569,100 sesterces raised by the local land owners.[570]

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[567] Margary (1973); Davies (2002).

[568] Russell (2016).

[569] Laurence (1999) 63.

[570] *CIL* IX 6075; Van Tilburg (2007) 35-36.

These numbers may be exaggerated to display the generosity of the emperor, but even so they do seem extremely large sums: varying local conditions might dramatically increase costs, such as the need for tunnels or large cuttings through solid rock.

Besides the quality of the surface and its width, the topography over which roads were travelling, and seasonal, weather, and biological factors could all affect how easy (or not) it was to travel by road (see below, Chapter 6.1.2.). These factors would of course have a highly significant impact on the speeds or distances possible to travel in a day on Roman roads. Again the ORBIS project has brought together a great deal of evidence in order to model road journeys across the ancient world, and suggest, as generalisations, mean daily travel distances of 12 km for ox carts, 20 km for porters or heavily laden mules, and 30 km for pack animals with moderate loads or mule carts.[571]

With regards to vehicles, as noted at the start of this chapter, water-logging and burial in anaerobic sediments often assist in the archaeological survival of maritime and riverine vehicles, as does the fact that on sinking they may be difficult to recover or salvage. Land-based vehicles on the other hand far more rarely end up in such preservation conditions, and if one was to be damaged or broken, many of its components might be fairly easily re-used. Thus, our corpus of Roman land vehicles is very small, compared to that of boat wrecks. Röring explored the archaeological evidence for passenger-carrying vehicles, in order to inform the reconstruction of one for the Rheinisches Landesmuseum, Cologne, based on the metal fittings found in a burial at Wardartal, Germany.[572] Complete wooden wheels were found in pits at Newstead Fort, Scotland, and local to this study a partial cart wheel was found at Gill Mill, Ducklington, Oxfordshire, and a cart side found in Dorney Rowing Lake, Buckinghamshire.[573]

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[571] URL = http://orbis.stanford.edu/#roadtime (Accessed 14/08/17).

[572] Röring (1983).

[573] Curle (1911) 292-293, Pl. 69; Booth *et al.* (2007) 314.

Artistic evidence provides perhaps some of our best evidence for the designs of Roman road vehicles. It can be difficult to always identify the animal being used, with donkeys, mules, and asses hard to tell apart. A relief from a 3rd-century AD tomb at Langres shows a four-wheeled wagon loaded with a large barrel pulled, seemingly, by *three* mules (and not oxen as stated by Raepsaet); very similar four-wheeled vehicles are also seen in reliefs from Cuneo (also loaded with a large barrel, pulled by two mules), Augsburg (again with a large barrel on board, pulled by two oxen), Strasbourg (carrying what look like sacks, pulled by two mules), and in a black and white mosaic in the Piazzale delle Corporazioni in Ostia, pulled by a single mule.[574] A fresco from Boscoreale is significant, showing two-wheeled carts at a construction site, and a similar vehicle can be seen in a relief from Arlon, Belgium, pulled by an equid being led by a man.[575]

Proxy Evidence from Finds

Nearly any find on a Roman site could be seen as illustrative of overland transport, and this is of course most significant with regard to non-local goods, and particularly at sites without direct access to navigable rivers or the coast. Thus the situation need not be discussed in much detail. As key local examples for this study the civitas capitals at St Albans and at Silchester are not proximate to navigable water-courses, and thus all movement of goods into and out of these centres must have been done by road for at least some distance; taking into account the food, clothing, tools, fuel, and building materials, this must amount to many tonnes of road traffic on a daily basis.

6.1.2. A Bumpy Ride?

Undoubtedly transport, particularly of the multiple tonne cargoes we are considering here of building material, would have been a very significant expense, and therefore in the

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[574] Molin (1984); Raepsaet (2009) 592, Fig. 23.5; Museo di Antichità, Turino; Römisches Museum, Augsburg; Musée archéologique, Strasbourg.

[575] Adam (1994) 216.

determination of the resultant region of dispersal; there is plainly some relationship between the distance travelled and the cost of transport, and therefore a notional limit to the distance a good might be moved before the cost of its transport became prohibitive to its purchase, and therefore distribution.

This of course was determined by how much someone was willing to pay for the commodity. At the extreme of construction in the Empire, DeLaine estimates that of the cost of building the Baths of Caracalla, more than 50 % of this might have been spent on transporting building materials rather than producing them.[576] Russell records that the price of simply bringing marble down from the Carrara quarries to the coastal port of Marina di Carrara, c. 10 km, in the 15th and 16th centuries, was equal to the price of buying the stone from the quarries in the first place.[577] Salzman suggests that in the later middle ages in Britain the cost of transport could outweigh the cost of production for building materials if the journey went over 12 miles (19 km).[578] An account roll for the construction of New College Bell Tower in 1396-7 records the expenses for both the labour of digging Headington Stone at the quarry, £15 15s. 11d, and for the carters to transport the 1386 loads of stone from Headington to the college, £23 12s. 4d, a greater figure in spite of the journey being under 5 km.[579] Nevertheless, building materials, even those far less prestigious than the highly sought-after, high quality white marble of Carrara, did often travel further than just a few kilometres, and perhaps we should be considering that in many constructions the transport costs may have been somewhere in the realm of half of the total cost.

A common motif in any discussion of the cost of ancient transport of commodities is the use of evidence from Diocletian's Price Edict, supplemented with medieval or early modern sources, to create ratios for the varying costs of maritime, riverine, and land

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[576] DeLaine (1997) 216-17;

[577] Russell (2013a) 104 (after Klapisch Zuber (1969) 209).

[578] Salzman (1992) 119.

[579] Rogers (1891) 306.

travel.[580] The broad consistency of the ratios calculated from the Price Edict with those calculated from later sources lends credence to the general conclusion that maritime transport was, by some way, the cheapest means of moving goods around, with river-borne trade the next cheapest (downstream cheaper than upstream), and road the most expensive. The ratio as calculated from the Aphrodisian fragment of the Edict is 1 : 3.9 : 7.7 : 42 (maritime, river downstream, river upstream, and road, respectively).[581]

However, as Russell warns, this ratio will be specific to the conditions of the time and region, and may not be applicable more broadly.[582] Doubtless the broad orders of magnitude shown by this ratio allows useful general conclusions to be drawn about preference for different transport means, and they give insight into the reasons behind certain trade goods travelling further than others, or the location of certain production centres or even urban sites. Attempting to work from just this ratio conceals a great deal of interesting and important variation in transport costs and times: every journey would be different, and would have multiple complex factors affecting its rate.

Complexity and variation will have been added to the journeys of building material by four main categories of influence: the character of the material, geographical and topographical factors, seasonal and weather factors, and human factors, each of which will be discussed below. Within each source of variation, further complexity is added by the means by which the material is travelling, using a vehicle of some sort, by pack-animal, or by hand. Indeed a material might move by several different means within its entire journey, and would need to be trans-shipped between the site of production and any vehicles or pack-animals used, perhaps between vehicles and stores, if utilising multiple transport means or if being transferred via a ‘middle man,’ and from the vehicle or pack-animal onto the building site.

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[580] Yeo (1946); Russell (2013b); Scheidel (2014).

[581] Erim *et al.* (1970); Russell (2013a) 95.

[582] Russell (2013a) 95.

6.1.2.1. Transporting Building Materials: the Character of the Materials

The physical character of the material clearly had a significant impact on the means and costs of transport, a key element missed by the over-simplification of transport costs to multiples of a standard maritime journey. Stone and ceramic building materials presented an array of different challenges to the agents in charge of haulage.

With the types of material under consideration in this thesis, huge monolithic blocks or columns are not a significant concern; such unwieldy objects undoubtedly presented additional significant, but surmountable, transport challenges to the Romans. The majority of the material under consideration in this study consists of relatively small units, either stones or ceramic objects. The shape and size of bricks, *tegulae, imbrices*, box flue tiles, and more-or-less shaped or faced stones for rough ashlar or petit-appareil style masonry lend themselves to being stacked, allowing large quantities of material to be efficiently and densely packed without wasting too much space. Further, neatly stacked cargoes are more stable and less likely to move around during transport, reducing the likelihood of upsetting the vehicle.

The average dimensions for *tegulae* in Britain are c. 43 cm by c. 33 cm, with flanges c. 5 cm high, and a weight of between 5 and 8 kg.[583] The average dimensions for *imbrices* in Britain are c. 43 cm by 17.5 cm, with a thickness of c. 2 cm, and a weight of between 3 and 6 kg.[584] Brick sizes could vary significantly, from two foot square *bipedales* (rare in Britain) down to c. 20 cm square *bessales*. Average densities of CBM are in the range of c. 1500 to 2000 kg per cubic metre. With these relatively consistent sizes and shapes it is possible to investigate how much material could have been moved at once, by hand, by pack-animal, and by vehicle, as is explored below.

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[583] Brodribb (1989) 12, 142.
[584] Brodribb (1989) 26.

Whilst CBM tends to come in broadly set sizes and shapes, it is impossible to generalise about stone, as sizes and shapes vary within and between buildings, dependent on the character of the geological deposit from which the stones were extracted and on the choices of the masons and builders. Thus where significant building remains are preserved it would be useful for blocks to be measured, an exercise that is only relatively rarely carried out, but one which is becoming easier with technologies such as photogrammetry and laser-scanning.[585] Most sedimentary rocks, including limestone and sandstones, have broadly consistent densities, ranging between c. 2300 and 2700 kg per cubic metre, dependent largely on the degree of weathering, porosity, and water content of the stone.[586]

The capacity of different vehicles to handle building materials varied hugely, with boats able to transport far larger quantities than standard road vehicles. In addition, for any cargo, space will be lost to interstices between objects, as well as dunnage (i.e. packing material) or any containers. “Stowage factors,” the inverse of “cargo density” (taking into account those extra considerations of interstices and dunnage) have therefore been used by ships’ masters to allow a more precise assessment of how much cargo might fit in a hold of a given volume, and to assist in positioning cargoes within the hold.[587] In order to use these the weight of one unit of cargo (in tonnes) is multiplied by the stowage factor (in m^3/tonne), and the total hold volume (in m^3) is then divided by this figure. For example, the stowage factor McGrail cites for marble blocks is 0.42 – 0.47 m^3/tonne, for wheat in sacks, 1.34 – 1.50 m^3/tonne, for earthenware in crates, 1.70 – 2.13 m^3/tonne, and that for tiles he cites as 2.13 – 2.27.[588] It is interesting to note how low the factor for marble blocks is, and how high that for tiles is. Presumably stone rubble might have an even greater stowage factor. Marsden uses stowage factors to offer theoretical calculations for the capacity of

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[585] Allen (2010); (2012).

[586] URL = https://www.simetric.co.uk/si_materials.htm (Accessed 30/07/17)

[587] McGrail (1989) 356, Table 1.

[588] McGrail (1989) 356, Table 1.

the Blackfriars I ship to transport certain cargoes, taking into account McGrail's stowage factors. Given the estimated hold volume of c. 28 cubic metres, and a cargo weight capacity of c. 50 tonnes, he calculates that the boat was therefore capable of transporting 36.4 tonnes of ragstone, 18.4 tonnes of grain in sacks, or 12 barrels of wine (totalling 15.33 tonnes).[589]

Turning now to road vehicles, we must consider traction animals. Varro comments that often vehicles were "drawn by mules yoked in pairs," and discussing the choice of animal: "some use asses, others steers or mules."[590] Mules, Raepsaet argues, were particularly advantageous for their robustness, being resistant to injury, their ability to work consistently for long periods, and their docile nature.[591]

For much heavier cargoes Raepsaet states that the bovine family, and oxen in particular, rank the highest in terms of sheer power output for the longest possible time, although of course this comes at the expense of speed.[592] With heavier cargoes simply adding more animals could work, and so the limiting factors became the strength of the vehicle, and the conditions of the road.

The potential capacity of carts in use in the Roman Upper Thames Valley has been discussed by the author elsewhere.[593] A reconstruction by Booth *et al.*, based on the find of a cart wheel from Gill Mill, Ducklington, Oxfordshire and the side panel of a Roman cart found at Dorney Rowing Lake, Buckinghamshire, and taking into account the artistic representation of a cart being pulled by two mules on a relief from Langres, north-eastern France, hypothesises a notional cart capacity of c. 2.5 m long, c. 2 m wide, and c. 1 m deep, a total volume of 5 m^3.[594] A survey of documentary evidence, combined with ethnographic

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[589] Marsden (1994) 195.
[590] Varro *de Re Rustica* 1.20, 2.8.
[591] Raepsaet (2009) 587.
[592] *cf.* Goe and MacDowell (1980); Cotterell and Kamminga (1990) 207; Raepsaet (2002) 31–64.
[593] Peveler (2016) 8.
[594] Booth *et al.* (2007) 314; Musées de Langres.

studies of cart capacities in later periods, suggests that four-wheeled carts pulled by either single or a pair of mules could transport between 500 kg and 1000 kg.[595]

Given how efficiently the regular shapes of some types of building material can be stacked, and similar to the calculations above for the Blackfriars I ship, weight seems likely to become the limiting factor before space does. Regarding carts, that c. 1000 kg weight limit would be reached before the c. 5 m^3 would be filled. Filling the above cart with *tegulae*, in terms of space, would entail packing c. 500 tiles on board, but this would weigh between 2500 kg and 4000 kg: impossible for the cart to hold, and probably beyond the means of even two mules to pull. Thus a cargo of just 75 – 150 roof tiles is estimated to be the maximum load which could be moved at once. Given the estimates for the number of roof tiles needed for projects given in Chapter 2, with c. 11 tegulae plus 11 imbrices needed to roof every 1 m^2 of floor area, even the smallest building projects might require multiple cart-loads of material, perhaps 10 – 20 cartloads for the small building excavated by Frere at Dorchester.

Evidence for the use of pack animals is in the Roman period is somewhat sparse, but it must have been important, and more recent analogy is informative. Raepsaet collects data on the loads and speeds possible from various animals, suggesting that mules could carry 150 – 180 kg in packsaddles up to about 24 km in a day or a load of 70 – 80 kg between 30 and 48 km/day, a horse at a walk could carry 100 – 120 kg c. 40 km/day, and an ass a load of 80 – 100 kg 24 – 30 km/day.[596] 70 kg of limestone roughly equates to a cube with sides c. 30 cm in length, whilst 180 kg equates to a cube with sides just over 40 cm in length, both feasible volumes, perhaps if divided into two, for packsaddles, although it would certainly take a very large number of loads to transport any significant portion of a building's materials. This makes the use of pack animals perhaps better suited to much

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[595] *Codex Theodosianus* 8.5; Raepsaet (2009) 598-600; Peveler (2016) 8.

[596] Raepsaet (2002) 68– 72.

shorter journeys for trans-shipping the material, leaving the long journeys for vehicles capable of carrying much larger volumes of material.

With regard to the final means of material movement, the transport of stone and CBM over short distances by hand, for loading and unloading vehicles, size, shape, and weight are again important factors. Ethnographic evidence suggests that porters and builders' labourers might carry loads of up to 150 kg over short distances, as cited by Raepsaet of London dockers.[597] Material dimensions were again important for the ease of manual movement, lifting, holding, carrying, and setting down; flat faces, a cuboidal shape, or tessellating shapes permit the possibility of more than one unit being carried by hand at once, being suited to stable stacking. Tools or mechanical means might assist with the manual movement of blocks: small winches with clamps are depicting moving ashlars in reliefs from the V*ia Cassia* and from Terracina.[598] With cuboidal blocks the use of a hod might have been suitable, although unattested. The well-known wall painting in the Tomb of Trebius Iustus on Via Latina, near Rome, depicts the use of baskets and amphorae split in half lengthways for the movement of bricks and mortar on the building site.[599]

6.1.2.2. Transporting Building Materials: Geographical and Topographical Factors

Geographical and topographical factors can have a hugely significant impact on the ease and speed of transport. Regarding maritime movement, dangerous currents and treacherous rocks or sand bars might all have regularly hampered shipping; the investment in coastal signalling in Britain since the Elizabethan Seamarks Act of 1566, and the numerous shipwrecks around British waters even in the post-medieval period, shows the significant dangers Roman period shipping faced. The English Channel is renowned for having very strong tides, with points around the Gulf of St. Malo and in the Channel

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[597] Raepsaet (2009) Table 23.3.

[598] Adam (1994) 43-58; Fig. 87 and 90.

[599] Connolly and Dodge (1998) 139.

Islands making up many of the top 50 largest mean tidal ranges across the globe.[600] The difference between mean high and low tides in St Helier, Jersey, is over 7 metres, and tidal streams can reach up to 12 knots in the Alderney Race. In comparison the Mediterranean has one of the lowest tidal ranges in the world, the greatest range being in the Gulf of Gabes at 1.5 metres, although the many straights between islands in the Aegean can create tidal streams of up to c. 8 knots.[601] Presumably local sailors would have had an excellent understanding of the daily and monthly rhythms of the shifting Spring and Neap tides, but nonetheless these would have had a very significant effect on the safety and speed of journeys. Navigation at night could have been particularly dangerous. Multiple accounts of hazardous voyages exist in the literature from the period, including those from Caesar and Tacitus above, but also the account of the shipwreck of Paul on Malta during his journey from Caesarea to Rome, and the account of Synesius, bishop of Ptolemais in Libya in the late 4th century, who, travelling from Alexandria back to Libya, ran aground two or three times before even leaving the harbour.[602] We know that the Romans did make use of lighthouses, following on from the most famous example of the Ptolemaic *pharos* at Alexandria.[603] Suetonius tells us about the lighthouse built by Claudius as a part of his new harbour at Ostia, and which we see depicted in multiple mosaics (such as those in the Piazzale delle Corporazioni), in relief sculptures (such as the Torlonia Relief, from Portus, dating to the late 2nd/early 3rd century), and in graffiti, from across Ostia, Portus, and Isola Sacra.[604] In Britain a pair of lighthouses are known from Dover harbour, the headquarters for the *classis Britannica*, and presumably also an important commercial harbour.[605] These lighthouses were in essence twinned with one at Boulogne, the other main base of the

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[600] US National Oceanic and Atmospheric Administration: URL = https://www.co-ops.nos.noaa.gov/faq2.html#26 (Retrieved 28/07/17).
[601] McElderry (1963).
[602] *Acts of the Apostles* 27; Synesius *Letters* 4.
[603] Strabo *Geographica* XVII.6.
[604] Suetonius *Claudius* 20.3; *cf.* collected evidence by Ostia-Antica.org: URL= http://www.ostia-antica.org/portus/c001.htm (accessed 10/08/17).
[605] Wheeler (1929); Booth (2007).

classis Britannica, which survived through to the middle ages, permitting its illustration on several occasions, but standing evidence does not remain today; Suetonius describes the construction of a *pharos* somewhere along the Northern French coast by Caligula, after his 'victory' over the Ocean, and Wheeler and others have conjectured that this might be the structure at Boulogne, Roman Gesoriacum, the departure point for Claudius' sail to Britain with reinforcements for the invasion.[606]

With regards to movement on rivers, rapids, bars, and shallows again could endanger travellers. Strabo notes that over a section of the Rhône merchants chose to portage their goods by land due to the swiftness of the river and the difficulties of sailing on it.[607] The tidal reaches of the Thames, with shifting and rapid currents would have required particular expertise to navigate. Again navigation at night could have been treacherous, forcing journeys to be broken up into daylight legs with overnight stops.

Regarding road travel, topographic and geographic factors would have had a huge effect on the rate of travel. Plainly the steepness of a road up a hill, relative to the cargo weight, determined the traction needed. Russell quotes that just a 1 % incline in steepness could double the haulage required to maintain the same speed, in the context of moving very heavy cargoes such as huge monolithic blocks.[608] Fig. 6.2 below shows that even in the relatively gently rolling landscape of Oxfordshire gradients of up to 14 % can be found on the main Roman roads, which would be enough to dramatically slow any traffic, and would especially hinder heavily laden vehicles. Current technical road design manuals state that for modern, engine-powered road vehicles, a 12 – 15 % gradient slows light vehicles by 10 – 15 km/h, and heavy vehicles by much more, with 15 % being the maximum negotiable slope.[609] Downhill travel can also be difficult and hazardous, particularly for animal drawn

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[606] Wheeler (1929) 37; Suetonius *Caligula* 46. Boulogne as departure point: Suetonius *Claudius* 17.
[607] Strabo *Geographica* IV.1.14.
[608] Russell (2013a) 108.
[609] Austroroads (2003) Table 10.1.

vehicles, and much slower speeds should be expected on these stretches as well as on the uphill segments.

Cargoes would not necessarily always have pristine, military built Roman roads along which to travel, having to make use of much rougher tracks in parts of their journeys. Terrain variation such as wet, marshy ground, or woodland, could all make movement far more difficult and slower.

6.1.2.3. Transporting Building Materials: Seasonal and Weather Factors

We have already seen how storms had a great impact on the Romans' use of the North Sea and English Channel, as recorded in literary sources. Beyond these, factors as simple as wind direction and speed could keep ships in port, leave them stationery in windless conditions, or multiply the speed of tidal streams. On both the sea and rivers a choice might be made between sailing and rowing (or towing), and thus variability in wind speeds, directions, and currents had the potential to make journeys far more difficult, perhaps doubling or tripling the effort or time needed to move a cargo. At sea visibility was of great importance, and so advection (sea) fog, occurring at rates of 2-3 % around the year in the English Channel and North Sea, could also stymie journeys.[610]

Broader seasonal variation can have a highly significant impact on the use of rivers for transport: water-levels can drop significantly in warm summer months, making navigation impossible, whilst in contrast heavy rains or snow melt in winter can put rivers in spate and cause them to flood, making both the river unusable, and potentially flooding nearby road networks, making fords impassable, or destroying bridges. From Rome we have numerous accounts of bridges over the Tiber being damaged or washed away, including, from Livy, two unnamed bridges being destroyed in a flood of 192 BC and the Pons Aemilius having its *tectum* torn away in 156 BC; from Dio and Tacitus we learn of the Pons

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[610] URL = http://weather.mailasail.com/Franks-Weather/How-Fog-Forms-And-Why (Accessed 28/07/17).

Sublicius being destroyed on four occasions in 60 BC, 32 BC, 23 BC, and AD 69; and again from Dio we hear of another unnamed bridge being destroyed in AD 5, which Aldrete assumes to be the Pons Sublicius, given its all-wooden structure.[611]

Heavy winds, beyond affecting movement under sail, might bring down branches or even whole trees, which can block rivers and roads, requiring significant manpower, and possibly animal traction, to move, and debris blown or washed into rivers might be a hazard to navigation, snaring boats. As a result of heavy rain landslips might occur in road cuttings or embankments, blocking roads and again requiring significant effort to clear. Puddles, pot-holes, and gullies might form in the road if drainage was not adequate, with freeze-thaw action and standing snow or slush further exacerbating the problem, breaking-up surfaces, reducing traction, making heavy loads very difficult to move, and creating the risk of slipping off the road, spilling a cargo, damaging the vehicle, or injuring the draught animals. The road surface excavated within the town of Dorchester itself has been shown to have had several phases of surface replacement, the old ones deemed too pot-holed to continue in use or even to be repaired.[612]

One example of this problem from the Roman period is recorded in Vindolanda Tablet 343, a letter from one Octavius to his brother Candidus, in which the former tells his brother he would already have gone to Cataractonium to collect a wagon (*carrus*) of hides "except that I did not care to injure the animals while the roads are bad."[613] The two dates mentioned in the letter, presumably in the near future, are the *ides* (13th) of January and the kalends (1st) of March, so it is reasonable to suggest that the author is writing sometime in the late autumn or winter.[614]

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[611] Livy 35.21.5-6; Iul. Obseq. 16; Dio 37.58.3-4; Dio 50.8.3; Dio 53.33.5; Tacitus *Hist*. 1.86; Dio 55.22.3; Aldrete (2006) 115-6.

[612] Booth (2013) 62.

[613] Vindolanda Tablet 343 lines 20-21.

[614] Vindolanda Tablet 343 lines 34-35.

6.1.2.4. Transporting Building Materials: Human factors

Finally, human factors might have an effect on the rate and ease, and thus cost, of journeys. Piracy at sea could put cargoes and lives at risk, and the scale of the problem in the Mediterranean is clear from the great effort and investment made in attempting to put a stop to piracy by Pompey, and then Augustus.[615] Presumably similar problems existed in the North Sea and English Channel, and the command given to Carausius, based at Boulogne, in AD 285, and the "Saxon Shore Forts," have been seen as indicative of this, and the Roman military response to Frankish and Saxon raiding and piracy.[616]

On land, highwaymen also seem to have been a problem, as we can identify from mentions in several literary sources. Strabo records that Augustus "put down the brigands" in northern Italy; Pliny, writing to Hispanus, discusses the disappearance of travellers on the road; and Epictetus muses on the options open to a traveller who has heard that the road he is to take is infested with robbers.[617] Suetonius tells us that both Augustus and Tiberius appointed soldiers for protecting roads from highwaymen.[618] Epigraphic sources and legal texts name *stationarii* and *beneficiarii* from the 1st century AD, soldiers stationed at *stationes* or *castella* on the *cursus publicus*, at bridges or gates into towns, in order to police traffic, keep the peace, and exact tolls and taxes.[619]

Dorchester provides a tantalising piece of evidence that fits into this narrative, with an altar found in the vicarage garden in 1731 (unfortunately now lost) set up by Marcus Valerius Severus, a *beneficiarius consularis*.[620] With Dorchester's location on a main road, and being on a crossing over the Rivers Thames and Thame, presumably a relatively high

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[615] De Souza (2002) 149 *ff.*
[616] Eutropius 9.21; Haywood (1991) 34; De Souza (2002) 225-229
[617] Strabo *Geographica* 4.6.6; Pliny *Epistulae* 6.25; Epictetus *Diatribae* 4.1.91.
[618] Suetonius *Aug*ustus 32.1; *Tib*. 37.
[619] Van Tilburg (2007) 66-68.
[620] Henig and Booth (2000) 39-40 and Fig. 2.3.

volume of traffic moved through it, using bridges or ferries, and possibly having cargoes trans-shipped from road to river, an activity which could potentially attract tax.

A further human factor to consider is that of traffic.[621] The above mentioned *Lex Julia Municipalis* bans wheeled traffic moving in the city of Rome during the day in order to reduce traffic congestion, and presumably other cities, towns, and even rural areas might be affected by this situation. If rivers were being used to the full extent of their navigability, upper reaches were likely only to be wide-enough for single vessels at a time, meaning boats might have to wait for one another, or heavier, slower vessels might be too wide to be passed by faster moving boats. Regarding the roads, again these might be too narrow in places for more than one vehicle to pass at a time. A meeting of two vehicles might entail one having to leave the road, a dangerous exercise that might lead to getting stuck, or one might have to attempt to turn, probably involving a great deal of effort trying to man-handle the vehicle, the un-hitching and re-hitching of the draught animals, and then the retracing of some distance to find a point suitable for the two vehicles to pass each other.

6.1.3. Moving Building Materials and Moving Food

As stated in the introduction, a comparison between the transport of bulk quantities of food, and the movement of building material, is interesting, with presumably similar logistical considerations. Also of interest to this comparison is the apparent rural nature of the production of both commodities: food being a primary product of countryside villa estates, and building material also often appearing to have been produced in the rural landscape, as established above (Chapter 5.4.2.5).

In considering the movement of food, our archaeological evidence for this particularly concerns amphorae. They are commonly found, are widely studied, the vessels themselves

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[621] Van Tilburg (2007).

are large ceramic artefacts, much like CBM; they of course act as a proxy for their contents, consumable commodities such as wine or olive oil. Besides amphorae we very occasionally unearth preserved wooden barrels, also representing the movement in large quantities of liquids such as wine. More difficult to identify archaeologically, but undoubtedly very important is the movement of grain, a key staple food: this was moved sometimes in amphorae, but perhaps more often in sacks. Textual and artistic evidence attests to their use, for example as depicted on the relief mentioned above from Mainz.[622]

Critical for this comparison, all of these cargoes were moved in quantities in which weight and bulk were significant obstacles, over significant distances, as set out below. We are thus concerned with a trade of multiple cubic metres of material, weighing multiple tonnes, travelling at least between rural production sites and their nearest urban centre, but often along much longer regional and even inter-regional networks of transport – a description that might fit both building material and food.

Regarding the question of quantities or weights of food, we can look at vessel capacities to gain a basic idea. A single, empty, Dressel 20 amphora has a weight of c. 25 – 30 kg, and a capacity of 60 – 65 litres of olive oil.[623] One litre of olive oil weighs c. 0.9 kg, and so a full Dressel 20 would weigh c. 80 – 90 kg. It is difficult to estimate consumption rates for oil in Roman Britain, with oil possibly being used for cooking, washing, and lighting (although alternative fats for all of these functions would have been found in Britain, where olive oil was presumably scarcer and more expensive). Nonetheless, at most just ten or so Dressel 20 amphorae might fit in a single cart load.

Marsden offers the dimensions for a barrel found reused in a well in London at Queen Street which measures 1.22 m high, has a 0.85 m "body diameter" and a 0.68 m "head

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[622] Ellmers (1978) 12-14.
[623] Peacock and Williams (1986) 52.

diameter."[624] Using the simplified formula for calculating the volume of a barrel, Volume $= \pi h(2r_1^2 + r_2^2)/3$, where r_1 is the body radius and r_2 is the head radius, this gives a volume of just under 0.6 m^3, 600 litres. The empty barrel would weigh somewhere between 60 and 100 kg, and so full would weigh 660-700 kg if containing wine. Roth considers that the daily soldier's ration of wine was probably about 0.25 l per day (to be watered down), although this sounds low compared to medieval figures: Martin records that peasants in 15th C. Languedoc consumed more than 1.5 l per day, peasants from Auvergne a similar amount, and part of the wages of a cowherd from Vernines (also Auvergne) in 1471 included 1 l of wine per day (although she does not note whether this was all to be consumed by the cowherd himself, or if he would share this with his family).[625] At these rates of consumption a single barrel might last 20 people one month; with these dimensions just one barrel was likely to be transportable by cart at a time.

Regarding grain, it is difficult to estimate the size of Roman sacks given that they have not been preserved. More recent comparanda would suggest that a 'sack,' as a medieval unit of measurement, would contain between 4 and 6 bushels of grain, weighing somewhere between 100 and 150 kg. Generally in Roman depictions grain sacks are shown as being carried one at a time by individuals, and so a weight of 50 – 80 kg might be more feasible, c. 2 – 3 bushels. Roth calculates that the Roman military grain ration, of 2 *sextarii* per day, would be equivalent to c. 850 grams of grain per day.[626] Presumably around 1 tonne would be transportable in a cart at a time, i.e. 10 – 20 sacks.

A very small settlement of c. 50 people might therefore require at least 40 kg of grain a day, or a tonne roughly every month, plus, with the high estimate, c. 50 l of wine per day, 1500 l in a month, i.e. c. 3 barrels, weighing nearly 2 tonnes. In a small town, with a

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[624] Marsden (1975) 12.
[625] Roth (1999) 39-40; Martin (2009) 74.
[626] Roth (1999) 24.

population of two or three hundred, as Dorchester's population might feasibly have been, this would equate to 4 - 6 tonnes of grain sacks and 12 – 18 tonnes of wine barrels.

The effort involved in sourcing these provisions would of course depend on the distance from which they were sourced. Presumably the greater part of the grain to such a small settlement would come from the surrounding agricultural hinterland, within 5 – 10 km of the town. For larger settlements, whose immediate hinterlands could not provide all the food needed, or when the desired commodity simply was not available in the vicinity, of course food would have needed to move over much greater distances. Pollen analysis in the vicinity of Silchester has shown that there appears to have been little cereal agriculture in the vicinity, meaning that town of c. 7,000 people imported significant quantities of grain.[627] The find of a large quantity of charred grain, up to a metre deep, at the Forum site in London, probably the remains of a shop which had burnt down in AD 60/61, is notable for the fact that the weed seeds within the deposit indicate that the grain's origin was somewhere in the eastern Mediterranean.[628] Wine and oil were imported from the Mediterranean, presumably either via the Rhône – Rhine riverine axis, or by the Atlantic, perhaps from Bordeaux. London certainly seems to have been the main port for the redistribution of continental goods, but ports at Chichester, Southampton, and perhaps even on the Severn may also have played a part for the west of Britain.

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[627] Fulford (1982) 403-419; Hanson (2016).

[628] Straker (1987).

6.2. Networks Available for Dorchester – Multi-Scalar Journeys

Having explored the broader picture across the Empire, the specifics of moving building material to Roman Dorchester on Thames are considered. The principal routeways from production sites to the building sites of Roman Dorchester could have included “major roads,” “minor roads,” and the rivers in the vicinity. Plausible itineraries, for different scenarios of production (“local” or “more distant” production sites), include the following:

- from a “local” production centre: utilisation of local main and minor roads for short distances (< 10 km);
- from “more distant” production centres: utilisation of major roads over medium and longer distances (10-50 km) with some use of minor roads to access these roads from production sites;
- from “more distant” production centres: utilisation of the River Thames and perhaps its tributaries for transport by boat, upstream or downstream, with the need for major or minor roads to access these rivers from production sites and to link the rivers to the town and its building sites.

Within all of these journeys the goods will have needed to be moved very short distances by hand for trans-shipment between post-production storage sites, vehicles, and sites of final use.

6.2.1. Local Scale Road Transport

CBM fabrics 1 and 2 demonstrate a mineralogical and chemical composition consistent with having been made from raw materials local to the town of Dorchester on Thames, e.g. the Gault Clay, available within c. 5 km or so. Similarly gravel, chalk stone, flint, and Upper and Lower Greensand were all available within a similar distance, not seemingly used for any significant construction but used on occasion for aggregate, or levelling in the case of the gravel.

Whilst CBM kiln sites have not been found in the direct region, such suburban production of CBM is known, for example, from Silchester (kilns at Little London, c. 2.8 km south west of the town), Canterbury (Kiln A located c. 530 m due north of the Roman town wall; Kiln B, 3 kilns, 137 m west of the town wall), and Colchester (Kiln 7 located c. 1 km west of the town wall).[629] A journey from the kiln site to building sites in the town would be undertaken presumably via a minor trackway directly into the town, or to one of the major roads into the town, and given the short distance, one vehicle and set of draught animals, or pack animals, could conceivably have made multiple journeys in one day, at a rate of 3 – 5 km/h or 5 – 10 km/h respectively. The landscape in the direct vicinity of Dorchester is relatively flat, with gradients only up to 2 or 3 %, and thus topography would be unlikely to pose too much difficulty for travel. However, the routeways involved may well run for some part of their distances through the floodplains of the Thames and Thame, and so bad winter weather could have created significant difficulties for these journeys, particularly in crossing the rivers, either by bridge or via fords.

Given these short journeys a model of direct relationship between producer and the patron in the town seems likely. It is even entirely feasible that production might happen on the patron's own agricultural land around the town. Alternatively, if another party was involved, it would be only a small matter for the patron to journey out to inspect the material at its site of extraction or production, or alternatively for the producer to bring samples of the material the short distance into Dorchester, perhaps to display at a market, or take directly to potential patrons. For such short journeys the costs of transport as a proportion of the total cost of material supply would be relatively small. However, regarding CBM, it seems unlikely that there was enough demand for the operation of a kiln on a perennial basis, and with the relatively poor quality of the stone in this immediate

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[629] McWhirr (1979b) Canterbury: 153-5, Colchester 126-7; Greenaway (1981) Silchester: 290.

vicinity of the town, these short networks would have been insufficient to furnish all of Dorchester's building material needs throughout the period.

6.2.2. Regional Scale Road Transport

The presence of CBM Fabric 8, produced at Stowe, Buckinghamshire, and of limestone possibly from the Portland Formation and from the Greater Oolites of the Cotswolds, show the use of material sources at a greater distance than 5 km from Dorchester, with road transport a feasible means of bringing the material to the town. This would entail the use of the major Roman road known as Margary 160 (running between Silchester and Towcester, via Dorchester and Alchester), and perhaps some use of Margary 16, Akeman Street, together with the use of minor roads at the start and end of the journeys to get from the production site to the main road, and to get from the main road to the building site.[630] Journeys of up to c. 50 km are therefore conceivable, which might take an ox-cart four days, or a heavily laden mule cart two days.

The major roads would have been used because they presumably provided a more reliable surface on which to travel. The route can therefore be discussed in more detail, particularly with regards to gradient and river crossings. In order to examine gradient a GIS was used to calculate the slope, in percent, of roughly every 100 m along the major Roman roads in the region from a 0.5 m resolution interpolated digital terrain model of the landscape. These are displayed in Fig. 6.1, with dark green representing a negligible slope of 0 – 1 %, lighter green 2 – 3 %, yellow representing a slope of 4 – 5 %, orange representing 6 – 9 %, and red representing 10 + %.

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[630] Margary (1973) 155-167.

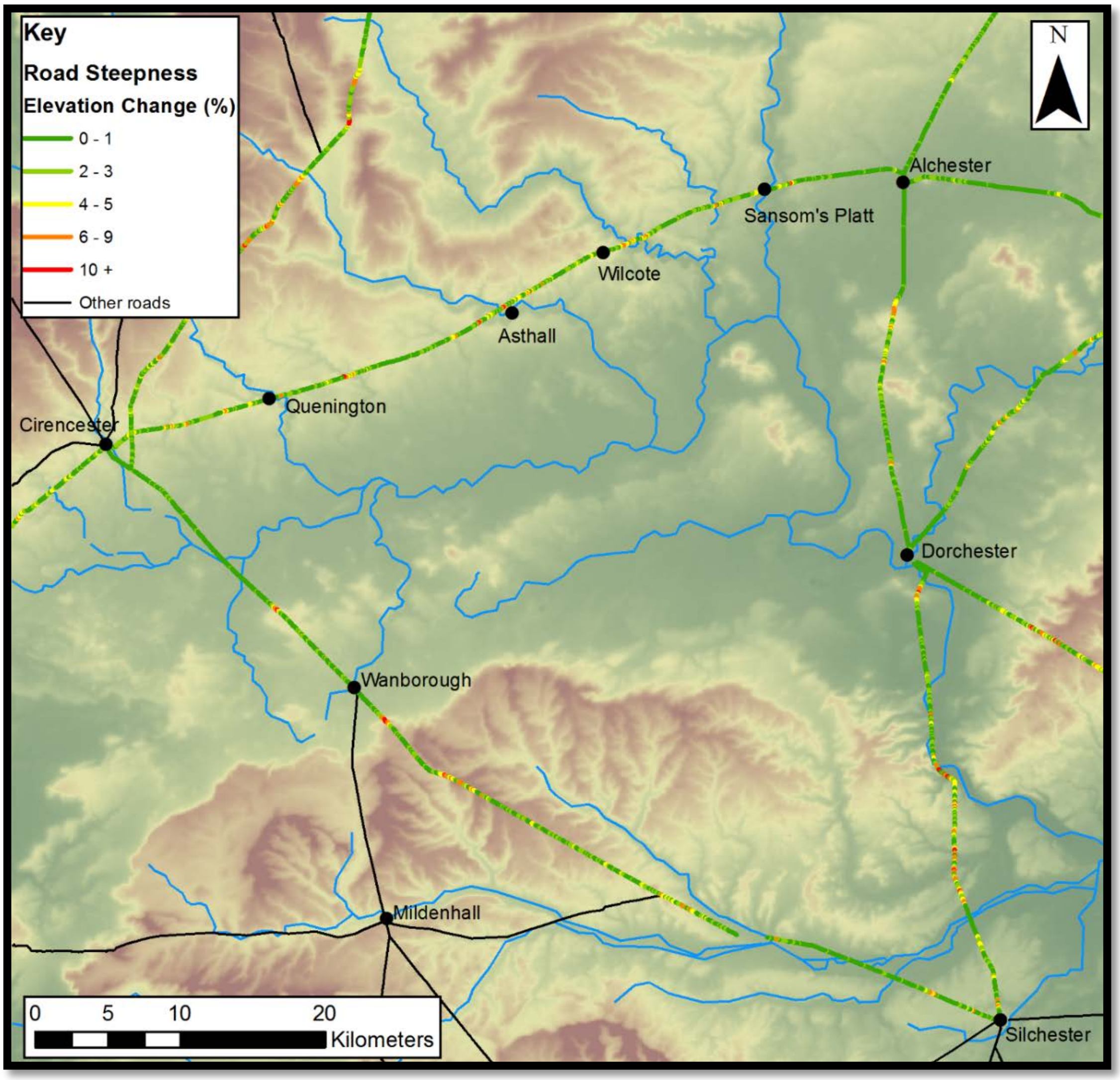

Figure 6. 1: Map of Roman roads in the region, colour coded by gradient (%) over 100 m intervals. Terrain data © Ordnance Survey (2017).

The steepest slope on the region's roads is 14 %, on Margary 160 south from Dorchester to Silchester as it rises out of the Kennet Valley. Shipments of material travelling along Margary 160 from Alchester to Dorchester, a journey of c. 26 km, would have to tackle several sections of 7 and 8 % gradients, particularly rising from Otmoor up onto the hill where the village of Beckley now is, and rising up onto the Portland outcrop around the village of Toot Baldon. Other significantly steep sections of road in the region can be seen where Akeman Street crosses the Windrush, Evenlode, and Cherwell Valleys, conceivably lying on the journey of building material from, for example, the East End Quarry in the Evenlode Valley from which Forest Marble tile-stone might be extracted.

These major routeways were also susceptible to seasonal and meteorological factors, although might be expected to be better maintained than the minor roads in use in the local scale distribution discussed above. Again heavy rains and snowfalls might decrease the quality of the road surfaces, especially with the heavy traffic that might be expected on such key inter-regional routeways like Akeman Street, running between the major towns of St Albans and Cirencester. Those steep sections of road noted above would become very difficult to pass with a heavy cart in wet or icy conditions, whilst low lying sections of the road, such as across Otmoor (marshy land just south of Alchester) and in the valley of the Evenlode, would be highly liable to floods in the winter. It has been suggested that the intensification of farming from the late Bronze Age onwards in the Thames Valley, and the replacement of woodland by grassland or farmland, significantly raised the water table of the Upper Thames, making flow rates more uneven and increasing the likelihood of flooding.[631]

These longer journeys mean alternative distribution scenarios should be considered, rather than simply the direct transit of material from production site to building site, involving only one (a patron moving material from their own land to a building site in Dorchester, or a producer bringing material directly to market in the hope of selling it), or two (a patron and a producer making an arrangement) actors. A direct relationship between the producer and the purchaser is made unlikely by the two-day journey between the site of production and the site of consumption. Instead a third actor, some kind of merchant or middleman, is plausible, perhaps based in a central market, or perhaps itinerant, moving between settlements. In the case of CBM Fabric 8 coming from Stowe and stone coming from the Great Oolite deposits of the Cotswolds, the location of Alchester presents the possibility of a nodal regional market.

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[631] Robinson and Lambrick (1984) 811.

6.2.3. River Transport

The location of Dorchester on, or at least within a short distance of, the Rivers Thames and Thame makes it ideally suited for exploiting riverine transport, connecting either local or more distant production centres with the town. Outcrops of the Great Oolite in the valleys of the Evenlode and Windrush might be made particularly accessible through riverine transport, saving considerable time and effort bringing the heavy cargoes by barge rather than road, firstly down to the main course of the Thames, and then continuing downstream to Dorchester. Taking the East End Quarry as an example, situated very close to both the Evenlode and Akeman Street, the following two routes can be reconstructed and compared for moving Forest Marble to Dorchester. Firstly, movement by ox cart along a minor road to Akeman Street, along Akeman Street to Alchester, and along Margary 160 to Dorchester, c. 48 km in total. Alternatively using the rivers, the journey would involve a 0.2 km overland journey to the Evenlode where it passes the quarry, a 15.4 km journey downstream on the Evenlode to its confluence with the Thames, and a 36.5 km journey downstream on the Thames to where it passes Dorchester; a 0.6 km journey by minor road into the town would be the final step, making a total journey of c. 53 km. Whilst this c. 52.5 km journey down the Thames is slightly longer than the 48 km journey by road, the riverine journey may well have been completed in one day, the road journey probably taking at least two days. In addition, a river barge might be expected to be able to carry several tonnes of material, in comparison to the c. one tonne maximum of a single mule or ox cart. Admittedly the barge might have required more crew, but considering the speed and volume benefits, would almost certainly cost fewer man hours per unit weight of building material.

Whether this journey would actually be possible along the Evenlode and Thames is a point of debate. The Thames in its modern form has been significantly altered from the Roman Thames in its course and character, through canalisation and the addition of regular pound locks. The construction of these was begun in 1631 with three (Iffley Lock, Sandford Lock, and on Swift Ditch, near the present Abingdon Lock) built by the Oxford-Burcot Commission, with many of the remaining locks on the Upper Thames built by the Thames Navigation Commissioners in the late 18th and early 19th centuries.[632] The question therefore of whether the Upper Thames could have been used for moving building materials in the Roman period is a challenging one, and one which has caused disagreement: Booth writes that the Thames was not navigable above Oxford in the period, whilst several authors, perhaps unthinkingly, but based on the proxy evidence from traded goods, assert the use of the river.[633] Our written record begins only in the mid-11th century, with the construction of the Swift Ditch cut at Abingdon by Abingdon Priory between 1052 and 1066, apparently to improve navigability of the river, carrying with it the implication that the river was indeed being used for navigation.[634] Peberdy goes on to record that complaints are regularly seen from the 13th century onwards about difficulties of navigation, culminating in the injunction ordering the removal of fish-weirs from the Thames and Medway in *Magna Carta* in order to "restore navigation."[635] By the 14th century it is suggested that Henley was the highest point to which the Thames "was ordinarily navigable."[636] The growth of Henley in this period can be attributed to this important location at the head of the navigable Thames: further evidence for the impassability of the river is offered by records such as the *Building Accounts of All Souls College*, 1438-1443, which note the purchase of Baltic softwood for doors and windows "brought up the Thames from London to Henley and stored there, before onward carriage over the Chilterns."[637] A possible cause for the decline in navigability is offered by Prior. She records that in this period the Thames was crossed by weirs, creating regular pools for powering

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[632] Thacker (1968); Peberdy (1996); Oliver (2010)

[633] Booth *et al.* (2007) 317; *cf.* Young (1977) 13, 234-5; Hayward (2009) 86.

[634] Peberdy (1996) 312.

[635] *Magna Carta* clause 33; Davis (1963) 28; Peberdy (1996) 315.

[636] Davis (1973) 267; Peberdy (1996) 312.

[637] *All Souls MS.* 401 f. 70v; Walker (2010) xx.

mills, but also allowing travel by flash lock, downstream with the flood, or upstream by winch; citing a legal case from the reign of Richard II in the late 14th century, she suggests that the disrepair of winches might have left boats unable to move upstream, restricting access.[638]

The picture painted of the medieval Upper Thames is one of multiple hazards and impediments to river traffic, but one that suggests traffic could, in the ideal circumstances, move along it, certainly up to Wallingford, probably Abingdon, and one suspects possibly higher. The obstructive mills would not have been a problem in the Roman period, but if not weirs at regular points, shallows, sandbars, and rapids might all have hindered progress. It seems probable that, given the dramatic time and effort savings discussed above of using the river rather than the roads, solutions to these issues might have been found. We have no evidence of Roman flash locks on the river, but the use of specialised shallow draft barges or punts (akin to the dug-out vessels from Zwammerdam, or the New Guy's House boat from London; see above Chapter 6.1.1.2.), the use of animal traction from tow paths, and the execution of journeys in winter months when the river was higher, would all feasibly have increased the navigability of the river, and made this very attractive method for moving heavy building material cargoes viable in this region.

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[638] Prior (1982) 109.

7. Conclusions – The Importance of the Ordinary

"We shape our buildings, thereafter they shape us." – Winston Churchill, October 28th 1943.

This thesis set out to shine more light onto the 'ordinary' buildings and building materials of the Roman world. It has emphasised how the construction of ordinary buildings, in an ordinary part of the Empire, using ordinary building materials, involved considerable effort, particularly to produce, trade, and use these materials. An insubstantial three-room building in a small town in southern Britain required nearly 100 tonnes of stone, roof tile, and timber, sourced perhaps from diverse producers and locations, and brought into the town, perhaps one tonne at a time. A close scientific analysis of an assemblage of building material from Roman Dorchester on Thames, combined with a broader survey of the surrounding and ongoing landscapes of production and use, has allowed a number of conclusions to be drawn, covering the full extent of the chaîne opératoire of building material.

7.1. Production Process

Beginning with building material production in Roman Oxfordshire, it is clear that there is significant influence on building material production sites from the geological, geographical, and human-made landscape.

Stone and ceramic building materials originate in geological raw materials, the physical characteristics of which were of great importance. The Dorchester CBM assemblage shows the Roman use of both bedrock and superficial clay deposits, but these were clearly carefully chosen, their processes of preparation and firing explicitly refined, to give consistently performing products (Chapter 4.2.1. and 5.4.1.). In choosing building stone (as a site with only limited choices in the locality), characteristic functionality for intended use was of prime importance, seemingly above considerations of proximity (Chapters 4.2.2. and 5.2.4.). Characteristics which were sought included fineness for shaping, resistance to weathering, and most noticeable was the exploitation of thin but still hard limestone and sandstone facies ideal for producing lightweight, durable roofing tile-stones.

Geographical features of the Roman landscape exerted influence on the location of building material production sites. It has been shown how Roman CBM kiln sites across Britain were broadly drawn to woodland and water courses (Chapter 5.4.2.), tile making requiring both fuel and water (with that latter relationship possibly also explained by transport considerations, below). Medieval and post-medieval stone quarries are shown to have been located in parts of the landscape with greater topographic variation, and also in the vicinity of rivers (Chapter 5.2.4.), the former aiding in the discovery and exploitation of rock outcrops, the latter again aiding in the transport onwards of these heavy materials.

Human factors of course cannot be ignored. Centres of population, both small and large, urban and rural, provided both the workforce and the demand for building material production. However, a fundamental characteristic of building material production is the space required for raw material extraction, whether clay pits, stone quarries, or managed woodland. As such it is not an activity well-suited to urbanised spaces, and the argument for rural, farm-estate managed building material production is presented below (Chapter 7.1.3).

The presence of soldiers in this region, particularly at forts at Alchester and possibly Dorchester, will have assisted in the identification and development of stone sources in the early years of the Roman occupation (Chapter 5.2.4.). Amongst the soldiery would have been masons, and there is a possibility that some would have used oolitic limestones in north eastern France, Belgium, and Germany, very similar to the oolitic limestones found in Oxfordshire. The construction of the road network may have further facilitated the discovery, and exploitation, of certain stones.

Following the conquest period, when stone quarrying and CBM production was mostly the preserve of military and increasingly municipal direction, came the development of new forms of elite expression in construction, using new, particularly Roman fashions of building in stone and ceramic (Chapter 2.4.). Private and municipal quarrying and CBM production must have expanded to facilitate material provision for the construction of public and private buildings in the walled towns of Oxfordshire, and also for the grander rural sites, particularly the villas. With these larger building projects, including the stone town walls of Alchester and Dorchester, and the villa sites, came extremely high demand for building materials: the relatively modest villa at Shakenoak required a minimum of around 600 tonnes of material (Chapter 2.5.2).

7.2. Logistical Organisation – no such thing as local?

With these extremely significant quantities in which very bulky, heavy goods were produced, even if materials only had to move over relatively short distances to their site of use, less than 10 km, or indeed less than 1 km, substantial consideration and investment in the logistics of moving the material needed to be made; a human might only be able to carry five or so *tegulae* at once with great exertion, and so draught animals and vehicles were needed if material needed to be moved more than a few metres. Beyond this, the analyses above for the Dorchester assemblage add to growing evidence from elsewhere demonstrating that, in spite of the difficulties inherent in moving such bulky material, it was not infrequently being transported over far greater distances, even for relatively modest buildings and mundane materials (Chapter 6.2.). The import of pink grog-tempered ware, Fabric 8, from Stowe, Buckinghamshire, and of tile-stones from the Cotswold Ridge, show that there was a market for material coming from distance, 50 km or more by road, the reasons for which are explored further below (Chapter 7.1.4.).

Transport costs could quite easily become a greater cost than the initial purchase of the material (Chapter 6.1.2), and so exploration of transport means and routes is critical. This thesis advocates Russell's view of looking beyond just "blue or black lines on maps" when considering how materials moved, and highlights key factors including the characteristics of the material itself, and the significant geographical, topographical, seasonal, weather, and human variables that building material 'shippers' would have faced on routeways (Chapter. 6.1.2.1-4).

The use of rivers in the Upper Thames Valley would have been a significant advantage in the transport of building material, allowing greater quantities of material to move greater distances per day than road transport allowed (Chapter 6.1.1.). It is a matter of debate to what extent the Upper Thames River and its tributaries were used, however, and this question is explored in some detail, concluding that, whilst the rivers were certainly not ideal, they probably would have been usable in the right conditions (Chapter 6.2.3.). However, this is not to diminish the importance of road transport, in spite of the relatively high costs associated with it. In every 'building material journey' some use of overland routes was inevitable, and in many cases it would have necessarily formed the major transport means (Chapter 6.2.1-2).

7.3 A Rural Economy

In Chapter 5.4.2.5 the possibility of the coincidence of building material production with villa sites was discussed, whilst in Chapter 6.1.3 a comparison between the movement of building materials and bulk food products was explored. It is suggested here that building material production was preferentially located in rural landscapes, where the space was available and access to the resources necessary for production (stone, clay, timber, and firewood) was straight forward. Elsewhere in the Empire, amphora production has been noted alongside CBM production in Central Italy and in the Guadalquivir Valley in Baetica, whilst the production of ceramic vaulting tubes has been linked with agricultural expansion in *Africa Proconsularis*.[639]

Villa estates pose a highly beneficial location for building material production. If an agricultural site was exporting its produce in ceramic containers, diversification of their products to CBM might have brought greater returns on the investment in a kiln and its attendant infrastructure, perhaps permitting output for a greater proportion of the year. The author has discussed the possibilities of coincident ceramic vessel and CBM production elsewhere with regard to Fabric 8, the pink grog-tempered ware, used for producing both large storage jars, weighing 20 – 30 kg empty, as well as *tegulae* and *imbrices*.[640] With these products similar in their thickness and bulk we might hypothesise that the particular clay, processing techniques, and firing undertaken at the site were beneficial for the properties of both, making the ceramics strong and durable enough to survive the demands put on them, and efficient to fire in terms of both fuel quantity and failure rate. The seasonality attendant to agricultural labour, with variation in the degree of activity throughout the year for an estate's work force, would lend itself well to auxiliary activities such as the production of building materials: stone could presumably be quarried at any time of year when surplus labour was available, and so too could clay be extracted, with exposure to winter rain and frosts beneficial to "souring" the clay and making it more plastic for working. Gathering fuel was traditionally a winter activity, when dead wood fell from trees. Forming and firing CBM might take place in the early summer, when the

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[639] Peacock (1977b); Chic and García (2004) 320; Lancaster (2012).

[640] Peveler (2016) 7-8.

weather allowed the wet clay to dry properly in advance of firing, but perhaps prior to the labour demands of harvest from late July onwards.[641]

It is likely even that multiple building materials would have been produced on one estate. Whilst generally a site of ceramic production is unlikely to occur in the direct vicinity of a site of building stone quarrying, one relying on clay deposits, the other stone, these resources might on occasion be found adjacent to one another, and rural estates might well include enough land to find both. Within 1 km of North Leigh Villa, a Roman tile kiln is known, probably exploiting the Kellaways Clay Member, as well as several post-medieval quarries extracting Chipping Norton Limestone Formation, White Limestone Formation and Forest Marble Formation stone (Fig. 7.1). The site is also within the boundaries of the old Wychwood Forest, which presumably would have provided both firewood and construction timber. The villa estate would almost certainly have exploited all of these materials for its own purposes, and might conceivably have made them available for others.

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[641] Warry (2006) 121.

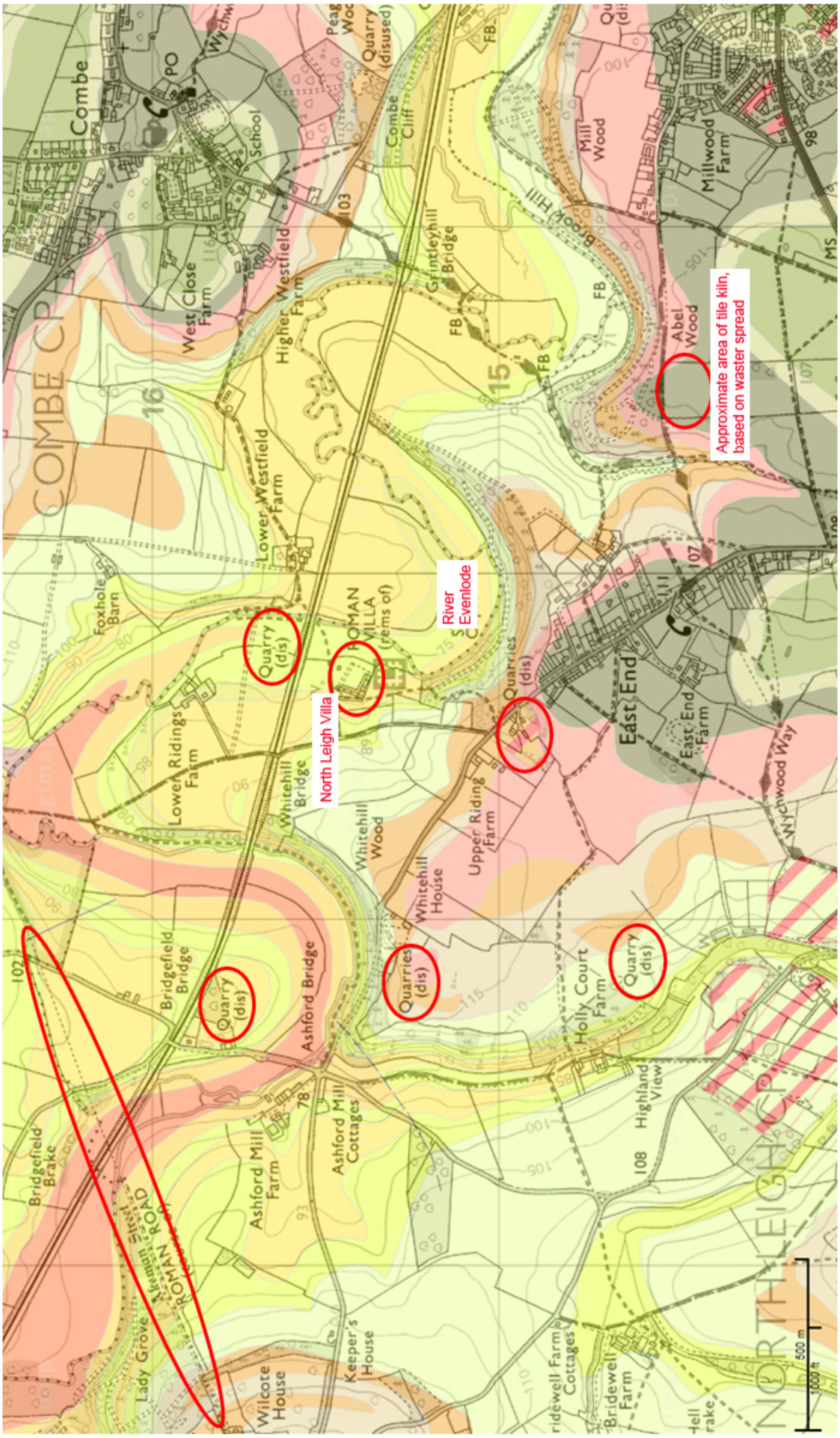

Figure 7. 1: North Leigh Villa set within a landscape of building material production and transport possibilities. Map data © OS (2017); geological data © NERC (2017).

A consideration of transport logistics adds further positive circumstances to the siting of building material production on villa sites: food production sites will have needed excellent transport connections for moving their products onwards to towns, the major sites of consumption. In the Upper Thames Valley villas can be seen clustering along the 'corridor' of Akeman Street, usually within 2 or 3 km, and often in close proximity to water courses as well. North Leigh Villa, above, was situated within a couple of hundred metres of the River Evenlode, and just over 1 km from Akeman Street. Building material production sites also benefit from good connection to transport routes. The transport of both food and building materials will, in addition to this, have necessitated access to vehicles and draught animals, employed on villa estates for ploughing and other agricultural activities.

7.4. Economic and Social Significance

Finally, the great economic and social significance of the building material trade must be emphasised. The choice, in Roman Oxfordshire, to construct a building in stone, or roof it with ceramic, must stand as one of the most overt ways in which a Roman-Briton could express their social and economic standing. These were techniques which had not been widely seen before the Roman occupation, certainly not in the region of the study area, and which must have come at significant expense, particularly in Dorchester, which was located away from particularly suitable building stone outcrops.

One key economic factor for consideration is the level of demand in the region, and whether that could support the existence of municipal or market-oriented tileries or quarries over extended periods. The difference in scale of use, and therefore production and transportation logistics, of building materials, compared with most other commodities, has been discussed above in terms of the "heavy good." However, whilst demand from an individual building site would be relatively extreme (tens, if not hundreds of tonnes, as shown in Chapter 2.5.2), the facts that relatively few buildings might be under construction at a time, and that a building might have a long life-span, need to be taken into account: some buildings might last for one-hundred, or even three-hundred years, therefore spanning a number of generations. Maintenance and repair of buildings will themselves have created certain levels of continuous demand, whilst the reuse of building materials, something which must have been a significant 'industry' in its own right, requiring specialist skills and infrastructure, will have somewhat reduced the demand for newly produced material.[642]

On the whole, demand for different building materials must have been highly sporadic, fluctuating month-on-month, year-on-year, and decade-on-decade. Unfortunately, on account of the highly incomplete archaeological record for buildings and production sites, and the difficulties of dating them, we do not possess enough data, particularly for the region in question, to resolve this fluctuating demand fully: initial booms of stone and ceramic construction in the early 2nd century, and the construction of the Alchester and Dorchester town walls will have put particular weight on production, but finer resolution mapping of demand requires further excavation. It certainly seems that the fluctuations and low overall level of demand in Oxfordshire would have favoured instead short-lived, private production, and indeed this model could explain the significant diversity in CBM fabric types within the small town of Dorchester, and perhaps the choice to import ceramic roof tiles from as far away as Stowe, Buckinghamshire: a more local source might simply not have been available at the particular moment that a demand existed.

The development of a building material production site would have been no small task: opening a quarry, constructing a kiln, and gaining access to the appropriate transport infrastructure (e.g. improvement of minor roads or tracks, and investment in vehicles and

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[642] Munro (forthcoming).

draught animals) would have been costly. This cost might have been offset by the linking of these activities with agricultural production, as described above. The significant threshold cost of initiating building material production might also go to explain why, when an estate does make use of stone or ceramic building materials, we see those materials used not just for the primary constructions but also for structures of lesser importance on that site, such as in the stone well house at Barton Court Farm, or in the "barn conversion" at Shakenoak Farm (Chapter 2.4.).

The change, from a world of earth, timber, and thatch architecture, to one in which large towns existed with pale, hard stone walls and bright, orange terracotta roofs, must have been a stark one. The way light and sounds moved in these centres of population would have been completely new to the region, and, being visible for all to see, new stone and ceramic houses must have been highly obvious expressions of identity, making use of new materials, and perhaps making use of materials not even found in the vicinity of the structure.

The choice of these materials might go beyond simple elite expressions of '*Romanitas*' however. Stone and ceramic buildings might represent a greater permanence of architecture, buildings put there to last, perhaps representing the hope of enduring wealth, power, or familial connection to a place. This should also not be seen in simple terms, however: timber and earth structures could themselves last for hundreds of years if well-built and maintained, just as stone buildings could, and the continual repair and alteration of stone structures in the Roman period is clear. Permanence may not even have been a governing principle in the construction of some buildings, a facet often assumed to be intrinsic, but which need not necessarily have been so.[643]

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[643] Smith (1970) 122-46; Mercer (1975) 1-9 and 23-39.

Stone walls and tiled roofs might represent greater security, in two ways. Firstly, from fire: the extreme flammability of wattle and thatch houses was a clear risk, and whilst stone and ceramic buildings were by no means immune from conflagration (with a proportion of the Dorchester building stone assemblage tinged pink, suggesting exposure to significant heat), they certainly reduced the risk. Secondly, these buildings might represent greater security of material possessions and of persons. With these buildings came new styles of lock, and there are several examples of Roman iron and bronze keys found at Dorchester. These two things together surely represent changing attitudes to the possession and protection of goods, property, and perhaps persons.

These changes seen in Roman Oxfordshire in the physical appearance of the built environment, in the possible functions of architecture, and of the linked changes in social identity and values, might usefully be viewed through the lens of the theory of vernacular architecture. The use of new materials (which might often be non-local) and construction techniques, to build buildings very different from traditional Iron Age structures such as roundhouses, sets Roman-style buildings as clearly not vernacular (Fig. 7.2). The use of new wall construction techniques, lime mortar, novel timber jointing techniques, or roof trusses or hips, will most likely have meant the input of a diverse, and relatively large number of people, probably including non-local tradesmen. The greater organisation required for using multiple different materials from a range of places, in ways which were not necessarily familiar, will have necessitated the input of building contractors, and even architects of a fashion.

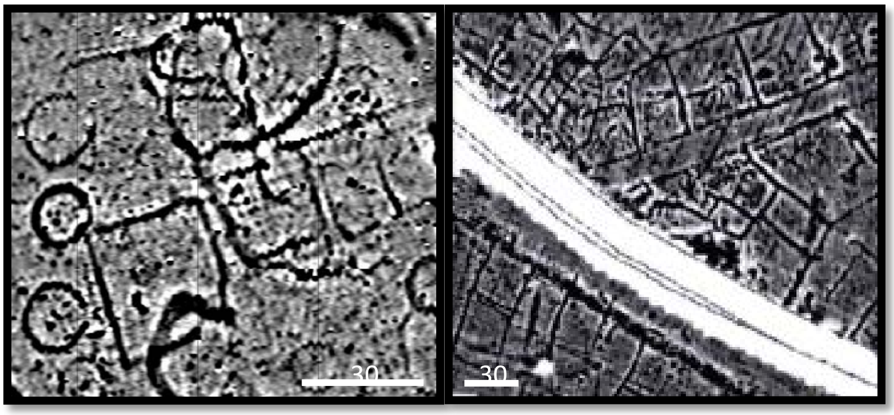

Figure 7. 2: Magnetometry of the middle Iron Age Dyke Hills Settlement (top, Wintle 2016) and Roman extramural settlement to the south east of Dorchester (Ainslie 2011). Grids 30 m square.

Further, we can look for the changing role of these structures as spaces for social expression. New Roman houses often had multiple rooms (as fully expressed by the large winged-corridor and courtyard villas of the region), in contrast to the predominantly single, or at least low number of rooms seen in Iron Age architecture, and this must reflect a dramatic shift in the function of indoor space, in terms of the activities carried out within them and the question of the more or less public and private nature of the space (also linked with the question of security). This seems an area ripe for further exploration, particularly in the regions of the Empire where pre-existing urban traditions and stone-building traditions were absent. Did these stone and ceramic constructional styles gradually become a new British vernacular architecture through the three centuries of Roman rule?

In sum, this thesis forms a plea for far more regular and rigorous analysis of ordinary building materials. The more these materials are studied, the easier they will become to study; building materials represent highly significant economic investment, and they signal overt cultural choices, changes, and identities. We thus stand to learn a great deal about a complex Roman industry, associated transportation networks, and the role of architecture, vernacular or otherwise, within the lives of the diverse peoples of the Roman Empire.

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Catalogues

Below are presented three catalogues: the first contains a survey of the geological units outcropping in the study area; the second contains sample descriptions, images, and raw chemical data from the CBM analysis; the third contains the sample descriptions and images from the stone analysis.

Catalogue 1. Geological units in the Upper Thames Valley

As set out in Chapter 3.2.4, clay for CBM production and stone for building stone production originated from a range of geological deposits, categorised as Formations, present in the Upper Thames Valley. These include both ‘bedrock’ (Jurassic and Cretaceous age) and ‘superficial’ (Pleistocene age) units. Below is a catalogue including detailed lithological and mineralogical descriptions of the major deposits outcropping in the study area, as can be gleaned from geological literature, with a key source being the *BGS Lexicon of Named Rock Units.*[644] Fig. 3.4 is repeated here for reference.

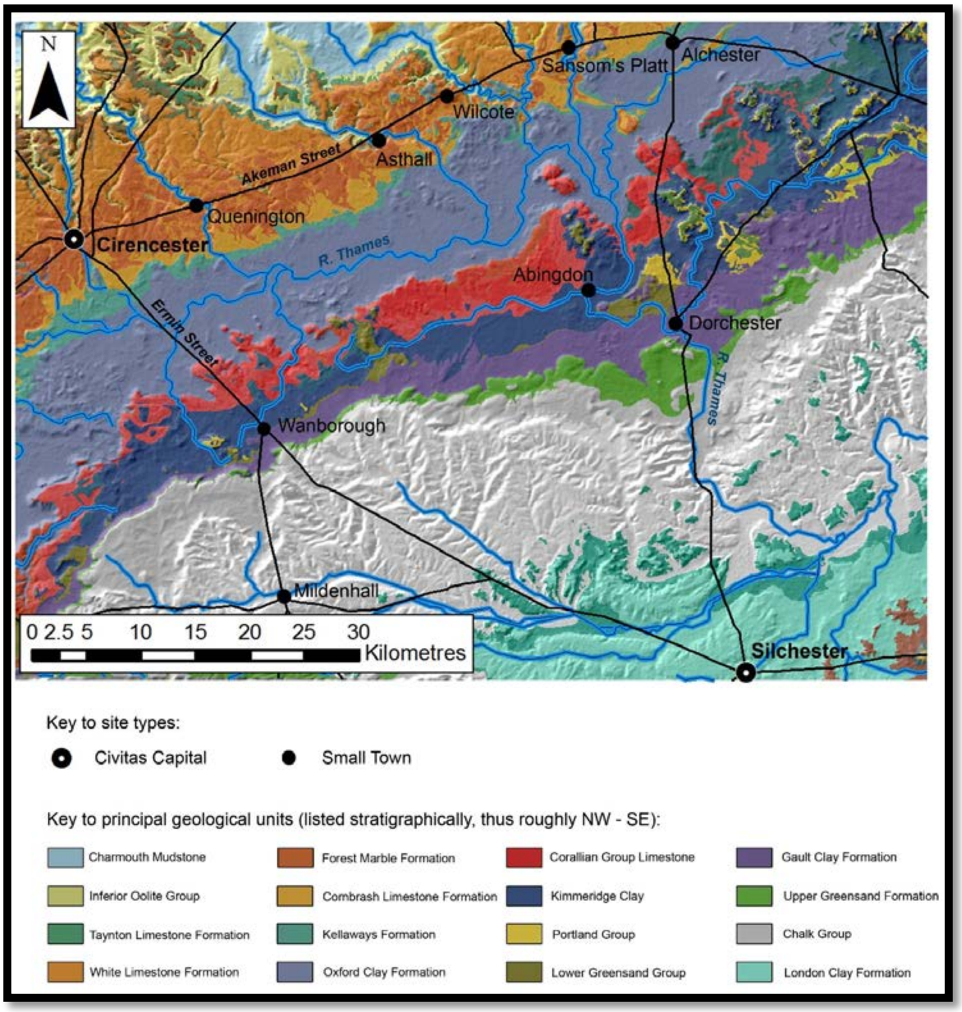

Figure C1. 1: (After Fig. 3.4) Major geological bedrock units of the Upper Thames Valley and its environs. Geological Map Data BGS © NERC 2015. Roman road data © Historic England 2015

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[644] URL = http://www.bgs.ac.uk/lexicon/home.html (Accessed 29/11/2017).

Bedrock Clay

Unfortunately due to the scarcity of mineralogical data on the more minor facies (Kellaways Formation, Ampthill Clay Formation, and West Walton Formation), here it is only possible to describe the three major bedrock clay formations of the valley in detail

The Oxford Clay Formation

The Oxford Clay was laid down in the Callovian to Oxfordian Stages, bridging the Middle and Upper Jurassic, 160-165 million years ago. Overlying the Great Oolite formations (see below), the clay represents a deepening of the sea off the London-Brabant Platform, a tectonic structural high running between western Germany and the Middle Thames; at that time of formation this sea was at the latitude of the modern Mediterranean. The clay formation extends across the country from the Dorset coast to North Yorkshire, outcropping in Oxfordshire along the base of the Thames Valley during its first west to east stretch, from Lechlade, through Oxford, to Ambrosden, just south of Bicester. It is divided into two facies, the Lower Facies, comprising the Peterborough Member, made up of fossil and organic rich fissile brownish-grey mudstones, and the Upper Facies, comprised of the middle Stewartby Member and the upper Weymouth Member, made up of medium to pale grey calcareous, fossil poor mudstones.

Whilst the geological maps do not make clear which facies or members outcrop where, evidence garnered from the building site of the New Bodleian Library in Oxford in the 1930s and a pipeline trench along Charlbury Road, also in Oxford, show the Stewartby Member and Weymouth Member to be exposed in the city, and given the tilt of the formation to the South South East, any exposures south of these locations will most likely also be of the so-called Upper Oxford Clay.[645]

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[645] Arkell (1938); Grensted (1954).

Mineralogical descriptions of these mudstones are unfortunately difficult to find in published literature. Spiller conducted an investigation in 1924 on samples from the Wolvercote brickworks, not identifying the member, but calling it a "stiff, plastic, dark-bluish clay."[646] He records that washing the clay "leaves a small residue, which consists mainly of iron-pyrites with a little quartz, less orthoclase, and a very small percentage of heavy minerals. The heavy minerals observed were garnet, tourmaline, cyanite, zircon, staurolite, and rutile. No unaltered mica was seen." He also noted that the clay was very calcareous, which would suggest that his sample may have come from the Upper Oxford Clay.

The mineralogy of the lower Peterborough Member has also been studied, giving the following suite of minerals in the raw clay: quartz, kaolinite, mica-illite, chlorite, plagioclase (albite), K-feldspar, calcite, aragonite, apatite, anatase, and pyrite; around 4.5% organic carbon is recorded as also present in bulk samples.[647] Notably experimental firings, to c. 1000 °C, of briquettes of the Peterborough Member clay have been carried out and published. During this experiment phase changes and reactions were noted, including the removal of absorbed water (c. 100 °C), oxidation and burning of organic material (200-450 °C), the dehydroxylation of kaolinite (400-650 °C), the breakdown of calcite (700-800 °C), and several other more complex reactions, dependent on temperature, soak time, and the minerals present or created by other phase changes.[648] These reactions are fairly difficult to predict, being highly dependent on the precise chemistry and mineralogy of each particular sample; "time temperature transformation" diagrams for phases of the clay allow some of the changes that occur to be scrutinised and ultimately a suite of minerals including quartz, mica, potassium feldspar, anorthite, pyroxene, anhydrite, hematite,

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[646] Spiller (1924) 176.
[647] Dunham et al. (2001) 222.
[648] Dunham et al. (2001) 226-229.

melilite, calcite, wollastonite, and amorphous glass are left to characterise bricks made from the Peterborough Member of the Oxford Clay.[649] It is unfortunate that the Upper Oxford Clay, which outcrops over large areas closest to Dorchester on Thames, has not been analysed in the same way.

The high organic content of the Oxford Clay, particularly the Lower Oxford Clay, means that during firing oxidation of these organics significantly reduces the fuel requirements of the firing.[650] This has led to the use of the clay in the brick industry in more recent times, and gave rise to the so-called "Fletton Process," named after the village of Fletton which sits on Oxford Clay, and which was the location where this technique was first extensively used. Whether the Romans exploited this fact remains to be seen, but if discovered could have made this clay a valuable resource for the firing of bulky loads of CBM.

The Kimmeridge Clay Formation

The Kimmeridge Clay Formation was laid down in the Kimmeridgian Stage of the Upper Jurassic, c. 155 million years ago. Overlying the limestones and sandstones of the Corallian, this clay again represents a deepening of the sea off the London-Brabant Massif, and extends on land from Dorset to North Yorkshire. The formation is divided, informally, into two main facies, the Upper and Lower Kimmeridge Clay, but these terms have little lithological bearing.[651] The stratigraphic reality has been shown to be a series of complex small-scale rhythms, 0.5-1.5 m thick, and larger-scale variations in the formation, tens of metres thick.[652]

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[649] Dunham et al. (2001) 223.
[650] Hudson and Martill (1994).
[651] Gallois and Cox (1994) 99.
[652] Morgans-Bell et al. (2001) 513.

Gallois and Cox give broad descriptions of the so-called Upper and Lower Kimmeridge Clay, noting that in the lower part of the Lower Kimmeridge Clay "these rhythms consist of thin silts or silty mudstones overlain by dark grey mudstones and pale grey calcareous mudstones," whilst in the upper part of the Lower Kimmeridge Clay and in the Upper Kimmeridge Clay "they consist of oil shales overlain by dark grey mudstones and pale grey calcareous mudstones."[653] The precise lithology and stratigraphy of the smaller-scale rhythms has relatively recently been re-assessed in two publications based on the drilling of three new cores through the formation near its type section in Dorset, giving a complete sequence through the clay, and extending the sequence from 49 stratigraphic units to 62.[654] These are categorised into four main repeating mudrock lithological types: "(a) medium-dark to dark-grey marl; (b) medium-dark to dark grey–greenish black shale; (c) dark-grey to olive-black laminated shale; (d) greyish-black to brownish-black mudstone."[655] The sections also contain subordinate amounts of siltstone, limestone and dolostone, demonstrating just how varied one formation can be, and how difficult it is to characterise them for our purposes.

The constituent mineralogy of the Kimmeridge Clay clearly changes considerably through the different units, and thus estimating the mineralogy of clay available for extraction by Roman brick makers is difficult: the published literature does not give details of the strata outcropping or close to the surface in the Upper Thames Valley. Neaverson gives some evidence that in Oxfordshire much of the Upper Kimmeridge Clay seems covered by the Gault Formation, and that it is the Lower Kimmeridge Clay that therefore outcrops.[656]

The general mineralogy given for the formation includes clay minerals (20–65 %), predominantly illite and kaolinite, with a smaller proportion of smectite and chlorite;

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[653] Gallois and Cox (1994); *cf.* Cox and Gallois (1981).
[654] Gallois and Cox (1994); Gallois (2000), Morgans-Bell *et al.* (2001).
[655] Morgans-Bell (2001) 517-521.
[656] Neaverson (1925) 242.

quartz silt or sand (12–40 %); carbonate minerals; pyrite; glauconite; and finally kerogen. Minor sediment constituents include fossils and shells (occasionally locally phosphatized), and plant debris. Neaverson gives a list of minerals identified in his study of the Upper Kimmeridge Clay, and the coarser sandy strata in particular, noting that they contain abundant well-rounded quartz, magnetite, glauconite, muscovite, chert, sphene, zircon, ilmenite, rutile, anatase, brookite, and a suite of other occasionally occurring heavy minerals.[657] However, the presence or absence and proportions of these minerals will vary with each different layer.

The Kimmeridge Clay has been used extensively in the post-medieval period for brick making, including locally at the Chawley Brick and Tile Works, Cumnor, in the 19th Century.[658]

The Gault Clay Formation

The Gault Clay Formation was laid down in the Albian Age of the Lower Cretaceous, c. 105 million years ago. In the Upper Thames Valley the Gault overlies the Lower Greensand, the two formations representing the alternate shallowing and deepening of a sub-tropical sea. The Gault outcrops extensively in eastern England, from Norfolk into the East Midlands and Home Counties, and further westwards into Devon. It also appears on the Isle of Wight and rings the margins of the Weald. The formation is divided lithologically into two parts, the Lower and the Upper, which, like the Oxford Clay Formation, are especially distinctive on account of the differing presence of clay minerals and calcite. The Lower Gault Clay consists mainly of soft, medium and dark grey mudstones, the clay minerals dominated by illite and kaolinite. The Upper Gault Clay is paler in colour on account of being more calcareous, and smectite dominates the clay mineral assemblage.[659]

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[657] Neaverson (1925) 248-253.
[658] Wastie (undated).
[659] Entwistle (1994) 4.

A sequence of smaller-scale rhythms or beds have been identified, but these are not as well documented as those of the Kimmeridge Clay.[660]

The principal mineralogical components of the clay are quartz (normally c. 20%) and calcite (as macro-fossils and shell fragments), together with minor (< 10%) muscovite and K feldspar.[661] Gale notes that "a few percent biotite and chlorite occur in Beds 1-4, the relative proportions of both decrease in subsequent beds," and continues to list chert, albite, garnet, mica schist, zircon, rutile, ilmenite and sphene as other rare components; Milodowski et al. note clinoptilolite and opal-CT found in the upper part of the Upper Gault from the core at Harwell, and also pyrite and gypsum.[662] The detrital matrix is generally made up of clay minerals, clay-grade quartz, mica and chlorite.[663] Again there are a lack of published data concerning the phase changes and reactions that occur during the firing of this clay.

The Gault Clay has been used in the post-medieval period for brick making, particularly in Kent.[664]

Superficial Clay

Glacial Deposits

Traditionally the so-called "Northern Drift" formation, the largest deposits of which lie in the vicinity of Bruern and Freeland on the south western slopes of the Evenlode Valley, has been described as a boulder clay or glacial till.[665] The deposit contains pebbles of quartz and quartzite originating in the Permo-Triassic or early Jurassic deposits of the Midlands, and the presence of flints has been attributed either to East Anglia or the

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[660] Owen (1971); (1975); Gale *et al.* (1996) 289.
[661] Entwistle (1994) 6; Gale *et al.* (1996) 293.
[662] Milodowski *et al.* (1985); Gale *et al.* (1996) 293.
[663] Gale *et al.* (1996) 293.
[664] Killingray (2010) 38.
[665] E.g. Sandford (1924) 121.

Chilterns, in directions contrary to the flow of modern drainage patterns, and thus these features have been interpreted as being the result of glacial action.[666] More recent re-analysis of the deposits suggests that whilst the material is indeed of glacial origin, that the morphology of the deposits as a whole is the result of fluvial activity, an ancient river flowing in what is now the Evenlode Valley from a higher ground in the Midlands, and also gathering tributaries from the Chilterns, mixing and redepositing glacial material into 'rude' gravel terraces and decalcifying them.[667]

Primary deposits of glacial clay are therefore very limited in extent across the county. Thus they are of little concern here, except for the possibility that material in the Thames gravels might have arrived from more northerly and easterly glacial deposits, transported by the extended Evenlode-Thames River.

Fluvial Deposits

There are two main elements to the fluvial deposits of the Upper Thames Valley landscape, the gravel terraces and the alluvium itself. The gravel terraces represent historical courses of the river at a higher level (Fig. A2). They also show the river to have followed slightly different channels to the modern course, which in the recent past has been carefully controlled by canalisation and lock infrastructure: the river has, through time, generally moved slightly to the south of its earlier course.

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[666] Sandford (1926) 108-9.
[667] Shotton *et al.* (1980); Hey (1986); Whiteman and Rose (1992); Sumbler (1995).

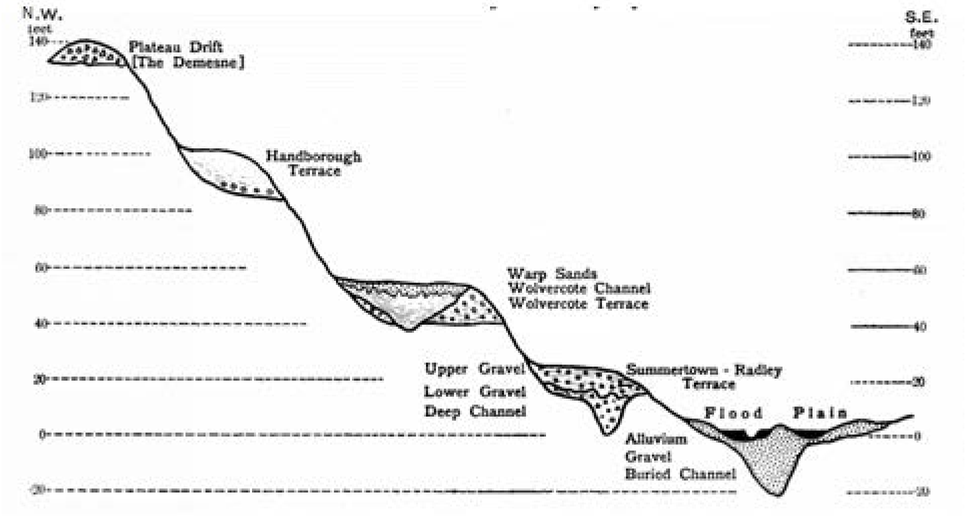

Figure C1. 2: Diagrammatic representation of the moving course of the Thames and the erosive and depositional impact on the landscape. After Sandford (1924) Fig. 17.

The process of the deposition of the gravel terraces is complex, with new deposits overlying older ones, before being eroded away, redeposited, and incorporating older fossils in the new terrace, ensuring that dating the terraces can be very difficult. However, the physical location and structure of the terraces, and their heights in particular, allow the sequence to be elucidated, with the Hanborough Terrace the earliest, the Wolvercote Terrace second, the Summertown-Radley Terrace third, and the so-called Flood Plain Terrace, part of the modern flood plain, the most recent, and indeed still under construction.

The gravel terraces attest to the powerful, juvenile character of the river, which results in alluvium or clays being relatively few and far between, only deposited when a particular channel of the river silts up and is not re-cut by the flow, or on flooding events. Alluvium, mineralogically, contains elements of the underlying bedrocks over which the river has flown, as well as sediment from the gravels, washed from the bedrocks of uplands such as the Cotswolds, or from the glacial deposits mentioned above. This means that the alluvial clays are very complex, containing residues of the Liassic and Oolitic rocks and iron stones from the north, quartzites, quartzes, and flints from the Freeland Sand and gravel Member, plus Oxford Clay, Kimmeridge Clay, Gault Clay, and elements from any tributaries to the Thames. In the Hanborough Terrace Sandford notes a sandy brown clay, in the Wolvercote Terrace a heavy ocherous clay and a sandy clay, and a silty clay in the Wolvercote palaeochannel.[668]

Modern alluvial deposits represent much the same thing, and so can be discussed here too. They also reflect the geologies through which the Thames and its tributaries flow, both bedrock and superficial. As such, the Thames just above Dorchester might be expected to contain material from the Gault Formation, the Lower Greensand, the Ampthill and Kimmeridge Clay, the Corallian limestone and sandstone, the West Walton Formation, the Stanford Formation limestone, Kingston Formation sandstone, and Oxford Clay. Added to this will be material brought down by the tributaries, such as the Ock draining from the Corallian limestone and Kimmeridge Clay, and the Rivers Cherwell, Evenlode, Windrush, and Coln with drainage basins on the Great Oolite Group, bringing Liassic material, Oolitic limestones, and ironstone into the deposit. The superficial geologies through which the Thames flows are principally of its own making, i.e. the gravel terraces, but might also include elements of the Freeland Sand and Gravel.

On the Thames beneath Dorchester we need also to add the sediments of the Thame drainage basin, which include many of the same geologies (Gault Clay, Kimmeridge Clay, Ampthill Clay, West Walton Formation, Oxford Clay), but also Portland limestone and sandstone.

Spiller gives a mineralogical description of three samples of river silt gathered from the brick works at Wolvercote (some way upriver of our site at Dorchester) from the silty clay of the Wolvercote palaeochannel. He describes it as a sandy pale-blue non-calcareous clay with irregular yellow patches, containing subangular and rounded quartz, feldspars

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[668] Sandford (1924) 124, 128, 133, 137.

(microcline and orthoclase), muscovite, magnetite, ilmenite, garnet, zircon, rutile and a few grains of chert.[669]

As noted in Chapter 5.4.1., several post-medieval brick and tile works exploited superficial formations, including the so-called “Northern Drift Formation,” probably equivalent to the reworked glacial deposits in the valley of the Evenlode, noted above, and the Neogene Clay-with-Flints, overlying the chalk in places in the Chilterns.

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[669] Spiller (1924) 176.

Stone

The Lias Group

Approaching this subject chronologically, we will start with the oldest outcropping deposits of the county. Due to the general downward tilt to the south east of the bedrock geology of the region, the oldest rocks outcrop in the north with the Lower-Jurassic rocks to the north of the Cotswold Hills. The primary building stone yielded by this group in the study area is from the Marlstone Rock Formation, also known as the Banbury Ironstone, of Pliensbachian to Toarcian Age, characterised as sandy, shelly, and oolitic ferruginous limestones, sandstones, and ironstones. Not only has this material been quarried for iron smelting, but is also commonly used as a building stone in the area of its outcrop and occasionally further afield, such as in the 19th C. Meadows Building of Christ Church College.[670]

The Inferior and Great Oolite Groups

Some of the most important building stones of the region come from deposits categorised as parts of the Inferior and Great Oolite Group. These sediments, laid down between c. 174 and 166 million years ago during the Aalenian, Bajocian, Bathonian, and early Callovian Ages, characteristically included a high proportion of ooliths, spherical, concentrically layered grains of calcium carbonate, giving rise to the various oolitic limestones found in the region. These demonstrate the deposition conditions of a warm tropical shelf-sea, akin to the present day Bahamas.[671]

The main formations which might have yielded building stone, including both blocks and tile-stones are, in stratigraphic order, the Chipping Norton Limestone, the Taynton

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[670] Horsfield *et al.* (2011).

[671] Cox and Sumbler (2002) 3.

Limestone Formation, the White Limestone Formation, the Forest Marble Formation, and the Cornbrash Formation.

The Chipping Norton Limestone is described as an off-white to pale brown fine- to medium-grained ooidal and peloidal grainstone with medium- to coarse-grained shell debris and minor amounts of fine-grained sand. Overlying the Clypeus Grit, and underlying the Sharp's Hill Formation, it outcrops extensively in the vicinity of Chipping Norton, and also further south, particularly along the sides of the Evenlode Valley near Charlbury. It has regularly been used as a freestone in these areas, and several flaggier facies have been used to provide roof tiles.

The Taynton Limestone Formation is described as formed of white to pale brown medium- to coarse-grained, ooidal grainstones with abundant and characteristic seams and wisps of shell detritus. It overlies the Sharp's Hill Formation, underlies the Hampen Formation, and has been quarried across north western Oxfordshire, particularly in the vicinity of Burford in the Windrush Valley and in the upper reaches of the Evenlode Valley. It has been used locally both as a freestone and for rubble blocks, and has been used extensively in the city of Oxford, used to build the 13th Century Mob Quadrangle at Merton College, the 15th Century Divinity Schools, and various more modern buildings.

Within the Taynton Limestone Formation can be found the famous Stonesfield Slate deposits, a fine grey micaceous and sandy limestone which easily splits into thin tiles, and can often be recognised by thin strings of oolites running parallel to the bedding plains.[672] These were widely used from the 15th – 20th centuries for roofing across the region, and come from a small area within a few hundred metres of the village of Stonesfield.

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[672] Boneham and Wyatt (1993).

The White Limestone Formation can be divided into three Members, including the grey to brownish sparry and micritic limestones of the lower Shipton Member, the white to buff micritic and sparry limestones with varying proportions of shell debris and peloids of the middle Ardley Member, and the creamy or whitish, cross-bedded, calcite-cemented shelly oolite of the Bladon Member.[673] Stratigraphically it overlies the Hampen Formation and underlies the Forest Marble Formation, and it outcrops over a very extensive area in the Cotswolds, including just north of Stonesfield, and in the area between the Windrush and Evenlode valleys. The limestones of the Bladon Member in particular are well known, having been quarried near Hanborough and used both locally and in Oxford, for example in the 14th Century library at Merton College and in various 19th and 20th century buildings such as Somerville College, Rhodes House, the New Bodleian, the Radcliffe Science Libraries, and the University Geology Department.[674] The other limestones of the White Limestone Formation are generally confined to local use as flaggy, rubbly walling stone.

The Forest Marble Formation is particularly characterised by blue-grey to buff shell-detrital sparry limestones, with varying proportions of ooliths, shell fragments, and micrite pellets. This formation overlies the White Limestone Formation and underlies the Cornbrash, and outcrops around the southern edge of the Cotswolds, particularly in the Evenlode Valley and in the area of the Wychwood Forest, after which it was named. Finer deposits of this stone can take a polish, and have been used amongst other places in the columns of the 17th century Canterbury Quadrangle, St John's College.

Finally, the Cornbrash Formation is described as a medium- to fine-grained bluish grey to yellowish brown bioclastic wackestone or packstone, generally poorly bedded, with occasional arenaceous or argillaceous interbeds. It overlies the Forest Marble Formation, and underlies the Kellaways Formation, outcropping along the very southern edge of the

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[673] Sumbler (1984) 55.
[674] Horsfield (2011).

Cotswolds where they give way to the clay vale through which the first stretch of the Thames runs. This stone rarely yields high quality building stone, used locally for rubble walling, but more often for lime burning.

Corallian Group

As we move forward in geological time, and south in the landscape, the next deposits of stone useful for building lie in the Corallian ridge, 10-15 km south of the southern edge of the Cotswolds, and forming the southern side of the Thames Valley in that first part of its course as it runs west to east. The ridge runs about 90 m above the bottom of the Thames Valley to its north, and to its south encloses the Vale of the White Horse, through which the River Ock runs to its confluence with the Thames at Abingdon. The ridge is made up of a complex stratigraphy of limestones, sands, and clays, overlying the Oxford Clay, and dating to the Oxfordian Age, c. 160 million years ago. The limestones, mostly part of the Stanford Formation, are generally a form of coral rag, containing dense shell fragments and coral remains, and are thus poor building stones, seen today used only very locally, generally in drystone walls for field boundaries.[675]

However, the Wheatley Limestone Member of the Stanford Formation does yield a better quality building stone, less shelly and bioclastic, and outcropping near Wheatley just to the east of Oxford. This stone was quarried from the end of the 13th century, and used for example in the walls of New College First Quad (c. 1380). The Headington Hardstone and Freestone are also part of the Wheatley Limestone Member, quarried in Headington on account of the massive, well-cemented limestone blocks that could be extracted. These have been used in the plinths of the Radcliffe Camera and Examination Schools, as well as in the construction of several colleges.[676]

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[675] Goldring *et al.* (1998).

[676] Horsfield (2011).

Portland Group

South of the Corallian outcrops, which are overlain by the Kimmeridge Clay Formation, and to the east of the now southward flowing Thames, lies an outcrop of stones of the Portland Group of the Tithonian Age. The Portland Limestone Formation found in the vicinity of Marsh Baldon, Toot Baldon, Great and Little Milton, and Great and Little Haseley, is a creamy-white, non-ooidal sandy limestone, which is used locally in buildings such as Great Milton church. Ooidal Portland limestone from its type-site on the Isle of Portland in Dorset is a very noteworthy building stone, having been used in major public buildings such as St Paul's Cathedral and Buckingham Palace, on account of its pale white-grey colour, resistance to weathering, and being well-suited to taking a fine finish. Whilst the outcrop in Oxfordshire does not yield such a pale or fine building stone, lacking the ooliths of the type-site, it remains a useable stone for rubble work in the vicinity of its outcrop.

Greensands

A few kilometres to the north of Dorchester lies a narrow outcrop of the Lower Greensand Group (overlying the Portland Group where this outcrops, or the Kimmeridge Clay) in the vicinity of Clifton Hampden, dating to the Aptian and Albian Ages. These largely unconsolidated sands seldom yield good quality building stones. On occasion limonite cement allows the formation of a pebbly gritstone, sometimes known as carstone, usable as a relatively poor quality building stone.[677] The Albian to Cenomanian Age Upper Greensand, outcropping directly south of Dorchester on the southern side of the Thames, and overlying the Gault Clay, consists of soft, very fine sandstones and siltstones, appearing pale bluish grey when freshly quarried, but rapidly weathering through decalcification to a very pale buff or whitish colour, resembling chalk.

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[677] Horton *et al.* (1995) 91.

Chalk

Finally, rising strikingly up in a steep scarp slope the Upper Cretaceous Chalk Group of the North Berkshire Downs and Chilterns forms the southern limit of the Upper Thames Valley. The constituent formations of the chalk occasionally yield better consolidated facies which can be quarried for ‘chalk stone’ or ‘clunch,’ i.e. a more durable type of chalk. This stone is still very soft however, and permeable to water. Secondly from within the chalk comes flint nodules, a very hard cryptocrystalline form of quartz. Whilst individual nodules are usually small, and require a great deal of skill to shape through knapping, these can be mortared together or used in rubble walling, as is frequently seen in the medieval buildings of towns sitting on the chalk such as Wallingford and Henley-on-Thames.

Catalogue 2.1. CBM Sample Catalogue

Sample ID: A1

Hand Specimen: Clay matrix a relatively consistent mid orange, although with frequent small to very large rounded clay pellets in yellowish cream and dark orange. Occasional large angular pores. Occasional large quartz inclusions. Relatively hard feel.

Thin section Description: Quartz the dominant clastic inclusion, range of sizes from small (abundant), medium (moderately abundant), and large (rare), often sub rounded, sub angular or angular. Well sorted throughout clay. Quartz can be seen in clay beads as well, with roughly the same shape and size distribution. Clay beads most obvious as pale cream colour, but some lighter orange beads, plus orange and cream clay streaks as well. Moderately frequent optically opaque, dark reddish black sub-rounded inclusions, plus streaks of the same material, identified as an iron oxide. Occasional very large angular pores, plus moderately abundant small – medium sub-angular and sub-rounded pores, possibly from quartz crystals being dragged out of the thin section during polishing.

SEM Description: A sample showing a moderately large amount of variation in inclusion sizes throughout. There are quite abundant medium and large quartz crystals, between c. 100 and 400 μm in diameter, generally sub angular or sub rounded, with pitted, rough edges. These have little interaction with the matrix, with a narrow space all around their circumference between them and the clay body. There are relatively frequent smaller quartz crystals and occasional potassium feldspar crystals, generally sub rounded, between 10 and 50 μm in diameter, and with some of the smaller ones showing much greater interaction with the clay body, their edges starting to merge into the clay. Throughout the sherd are occasional heavier inclusions, including iron oxides (spread through areas of clay up to c. 100 μm), and titanium dioxides (anatase or rutile), generally < 5 μm. The clay body itself has a vaguely platey character, but is generally tightly bonded, with narrow, longitudinal cracks and pores, on a larger scale (in the region of 50 – 100 μm long), and on a much smaller scale, < 10 μm long.

Chemistry: Relatively high Al and Si; relatively low K, second lowest Ca (essentially nothing).

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
A1	67.92	20.77	0.06	6.59	2.39	1.22	1.06

Fabric: Fabric 4

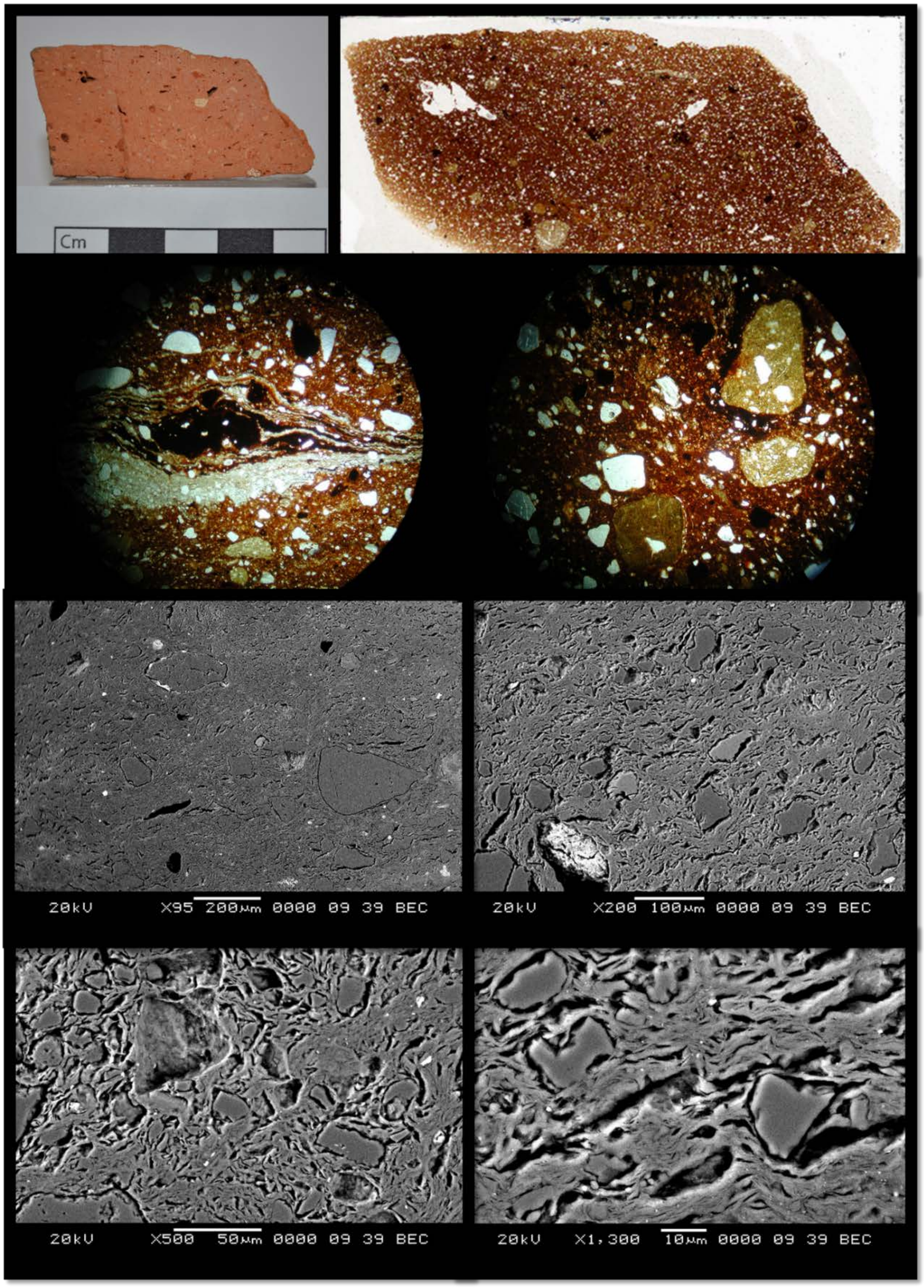


Figure C2. 1: Sample A1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: A2

Hand Specimen Description: Light to mid orange clay body, with moderately abundant medium and large quartz inclusions. Rare large to very large rounded clay beads in dark greyish red, cream, and reddish orange colours. Moderately abundant black shiny inclusions, presumably iron oxide. Quite apparent small up to large longitudinal pores, aligned east-west. Low-to-moderately abundant small, rounded pores.

Thin Section Description: N/A

SEM Description: A 'busy' looking fabric, with mixed sizes and shapes of quartz (large and very large, between 100 and 800 µm, rounded or sub rounded; medium, between 50 and 100 µm, angular or sub angular; small, 10 – 20 µm, rounded or sub rounded) and relatively high levels of potassium feldspar, in the large and medium categories, and with similar shapes to the quartz. Moderately abundant iron inclusions, both large and small, plus small and very small ilmenite, titanium dioxides, and rare zircon. Relatively smooth, highly sintered matrix, with hints of plateyness and occasional longitudinal cracks or pores, some c. 200 µm long, so 20 – 30 µm long.

Chemistry: Mid Si, higher end of Al, essentially non calcareous (1%), 3rd highest Fe. Otherwise midling.

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
A2	63.32	20.50	0.99	8.52	3.90	1.72	1.06

Fabric: Indiv.

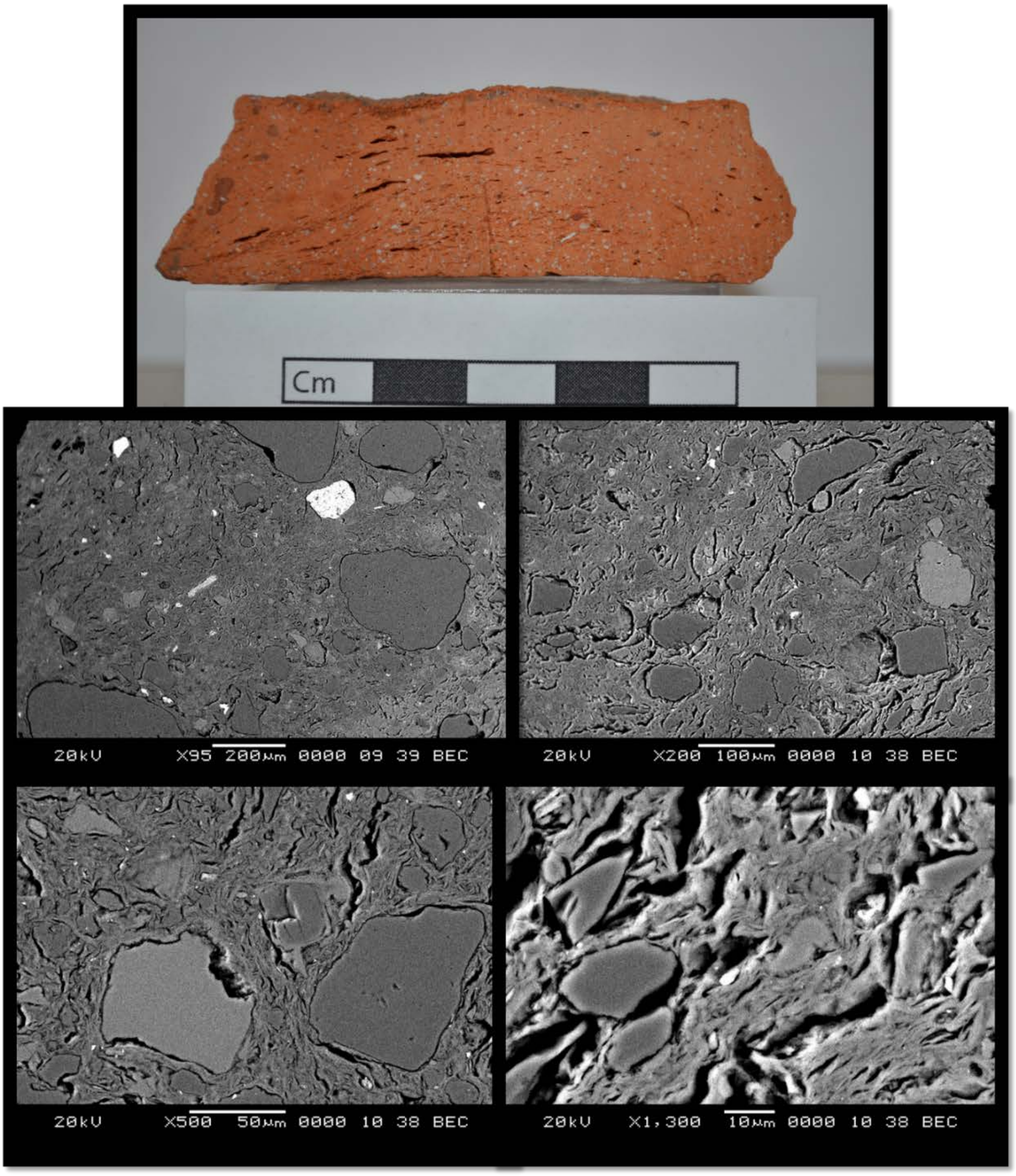


Figure C2. 2: Sample A2 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: A3

Hand Specimen Description: A mid-orange fabric throughout with moderately abundant mixed small and medium rounded quartz inclusions. Infrequent rounded pale cream and rare dark orange clay beads. Occasional small rounded black inclusions, sometimes seemingly burnt out. Low-to-moderately abundant small rounded pores, sometimes somewhat elongated.

Thin Section Description: N/A

SEM Description: Abundant quartz of mixed sizes, generally rounded, including large (c. 100 to 400 μm), small (30 – 50 μm) down to very small (< 10 μm). Small quartz interacting strongly with matrix, quite highly sintered. Only very rare potassium feldspar, occasional large irony clay beads (up to 200 μm), and occasional very small titanium dioxide and zircon. Discrete rounded separated parts of the clay body, seem to be small clay beads, but same chemistry as rest of matrix. Relatively smooth looking paste with few pores; some hints of plateyness remaining, and occasional longitudinal cracks/pores, up to 100 μm long. Voids where medium and larger quartz have been dragged out by polishing.

Chemistry: Mid Si, 4th highest Al, just over 1% Ca. Higher end of Fe. Low end of K and Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
A3	63.69	22.67	1.20	7.83	2.57	1.44	0.61

Fabric: Indiv.

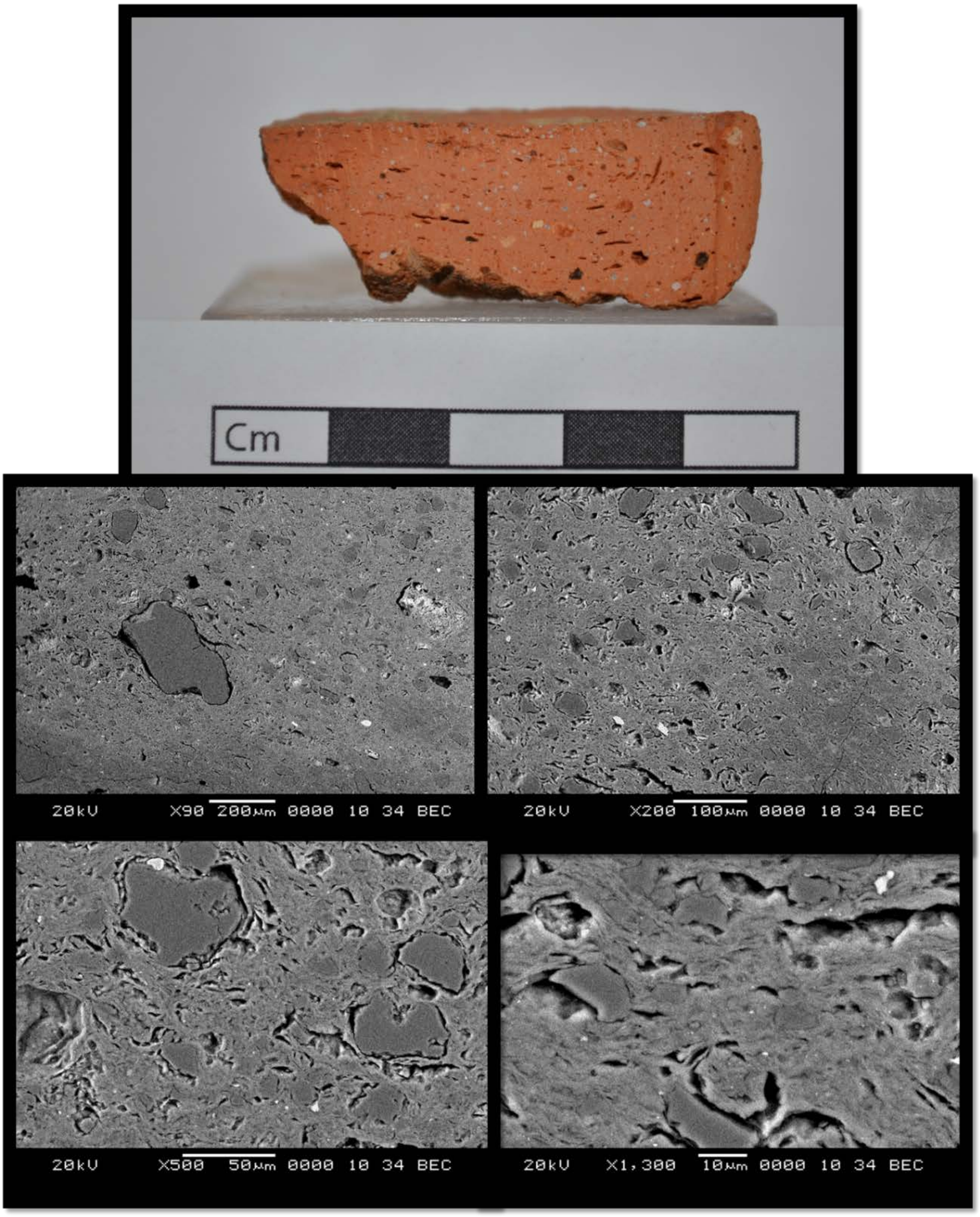


Figure C2. 3: Sample A3 in hand specimen and in SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: (L)A4

Hand Specimen Description: A mid-orange fabric with low to moderately abundant mixed medium and large rounded quartz inclusions. Very rare rounded cream clay inclusions, rare dark orange rounded clay inclusions. Clusters of red-black rounded inclusions, presumably iron minerals. Moderately abundant small round pores, some slightly elongated.

Thin Section Description: Moderately frequent quartz, generally very small and sub-angular. Some much larger sub-rounded quartz, bimodal distribution suggestive of tempering. Also large not well sorted – can just about see lines of large quartz where not well mixed. Moderately frequent optically opaque reddish black grains, iron oxide, generally round and large, but smaller spread throughout clay. Moderately frequent medium – large pores, generally rounded.

SEM Description: Infrequent sub-rounded quartz of up to c. 400 µm diameter, moderately abundant sub-rounded quartz of c. 100 µm, and abundant small, sub-angular quartz c. 20 – 30 µm. Moderately abundant amounts of potassium feldspar, in same size group as these small quartz inclusions. Relatively high levels of heavy inclusions such as iron minerals and anatase. Highly platey texture, with well aligned longitudinal pores, and little interaction between clay body and inclusions, with little sign of a liquid phase having been formed.

Chemistry:

One of lowest Al, highest Si. Low Ca. Second lowest Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
LA4	71.59	16.87	0.25	6.25	3.55	1.15	0.34

Fabric: Fabric 1

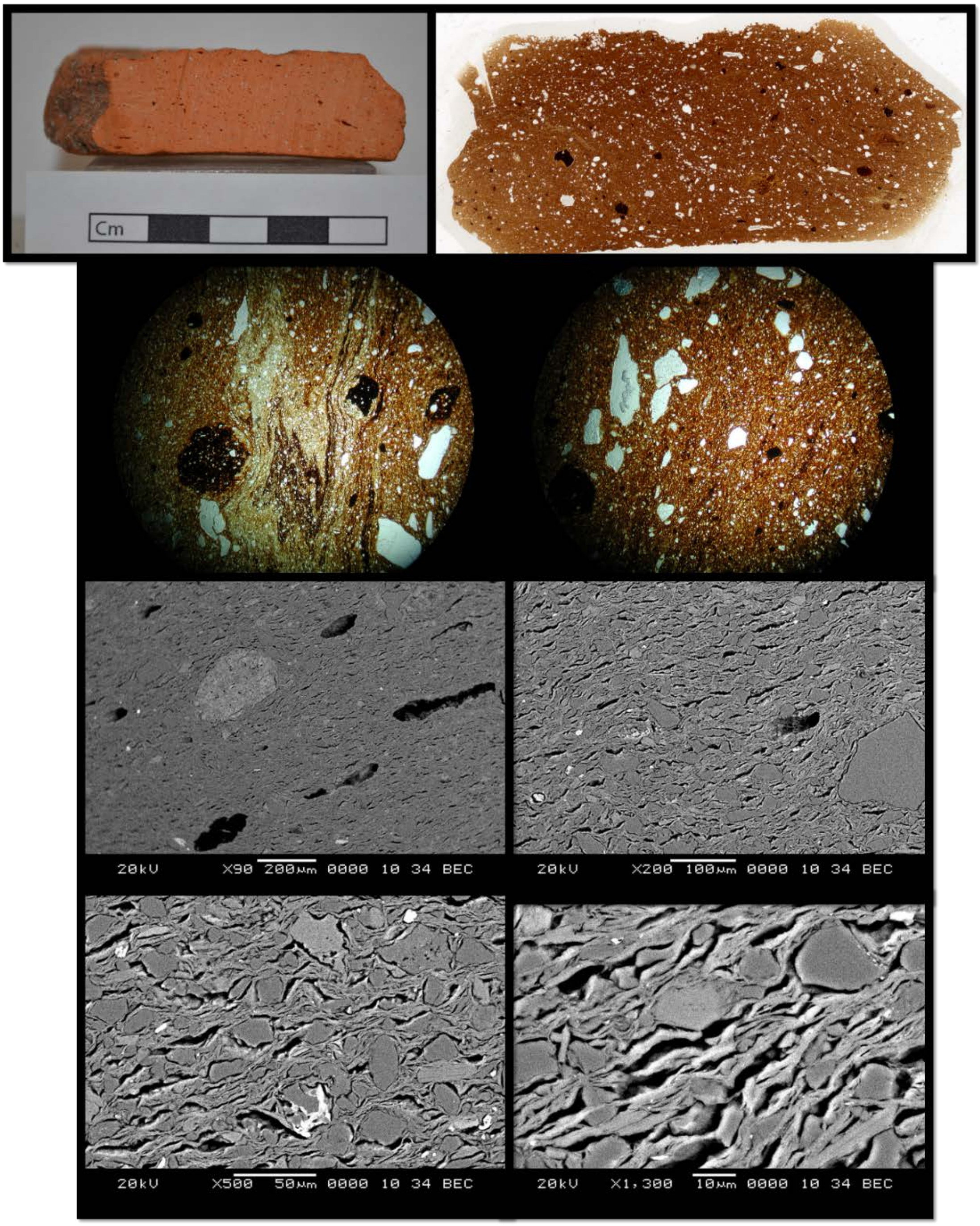


Figure C2. 4: Sample A4 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: (L)A5

Hand Specimen Description: A pale to mid orange fabric with low to moderately abundant large and very large quartz crystals, rare large clay beads in a creamy white and a darker red clay. Some relatively small longitudinal pores are apparent, running east – west.

Thin Section Description: Appears very similar to A4, mid to dark orange matrix consistent throughout, with occasional swirls of darker red and cream clay. Some very large quartz, sub angular, and some very small sub-angular, bimodally divided again. Large quartz not well sorted, appears in two lines through section. Moderately frequent iron oxide inclusions, small and rounded and some larger smudges. Some large angular and medium rounded pores.

SEM Description: Again very similar to A4: Infrequent sub-rounded quartz of up to c. 400 μm diameter, moderately abundant sub-rounded quartz of c. 100 μm, and abundant small, sub-angular quartz c. 20 – 30 μm. Frequent potassium feldspar, in same size group as these small quartz inclusions. Quite frequent small iron oxide and other heavy mineral inclusions (anatase, ilmenite). Again a highly platey texture, with longitudinal pores between sintered clay minerals, and little sign of vitrification.

Chemistry: Second highest K. Low Ca. Third lowest Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
LA5	66.49	19.68	0.22	7.30	4.50	1.43	0.37

Fabric: Fabric 1

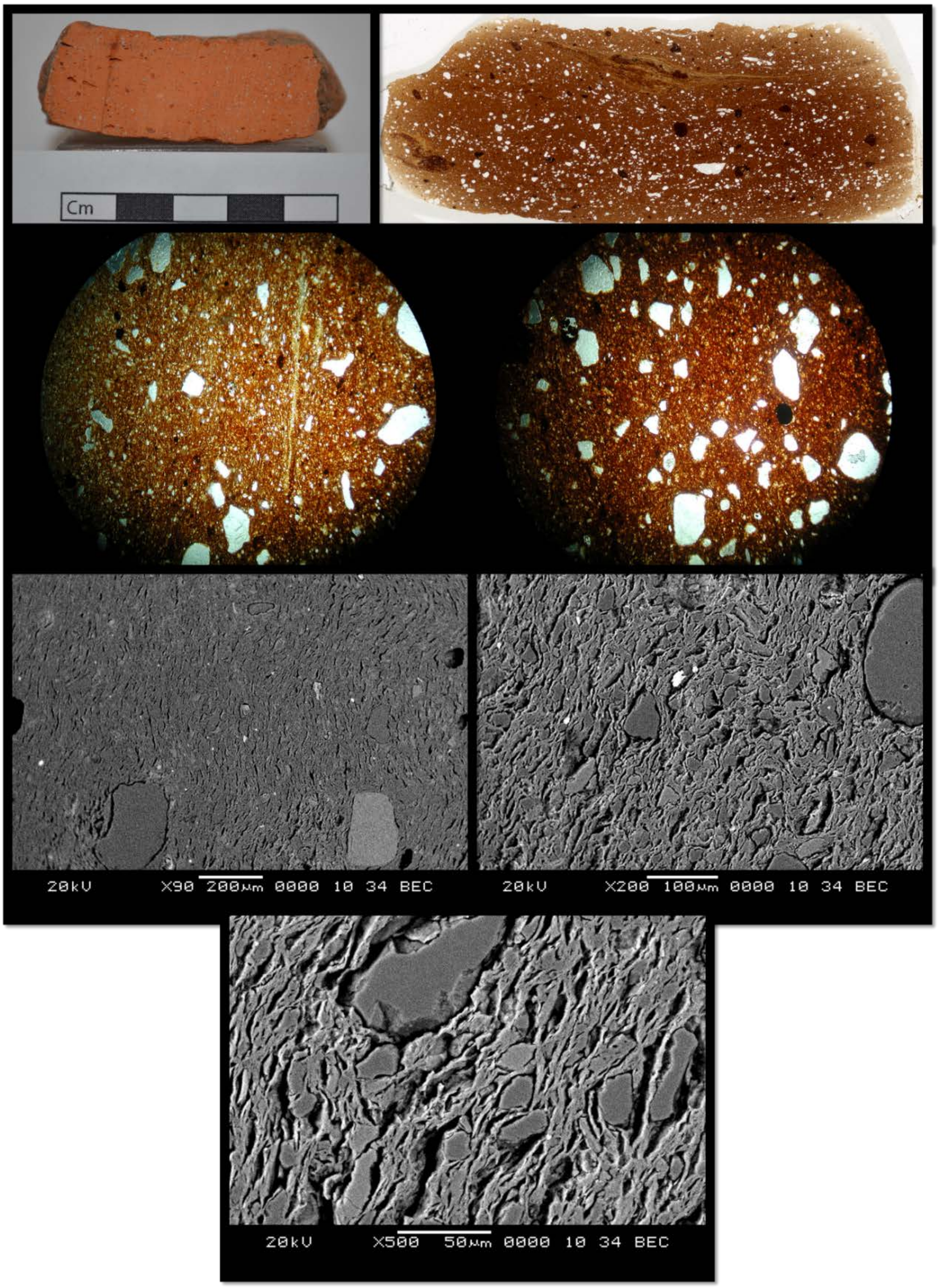


Figure C2. 5: Sample A5 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 90, x 200 and x 500 magnification.

Sample ID: (G)A6

Hand Specimen Description: A mid orange outer and pale bluey grey core. Dominated in hand specimen by frequent smaller rounded and larger longitudinal pores, most apparent in the blue core. Occasional large quartz crystals, and rare very large reddish rounded clay beads. Hard feel with sharp breaks.

Thin Section Description: N/A

SEM Description: Infrequent large sub angular and sub rounded quartz inclusions, up to c. 300 µm in diameter, with a similar size fraction and frequency of iron rich clay beads. Occasional medium sub rounded quartz, 50 – 100 µm, and moderately abundant sub rounded small quartz, 20 – 30 µm. Occasional small angular potassium feldspar, similar size to this. Occasional other heavy minerals, including titanium dioxides and iron oxides. Longitudinal pores with slightly platey clay body, but this has begun to vitrify slightly, pulling the clay minerals close together.

Chemistry: Highest Al. Lowest, no Ca. Highest K.

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
GA6	62.72	23.46	N/D	6.18	5.05	1.52	1.08

Fabric: Fabric 1

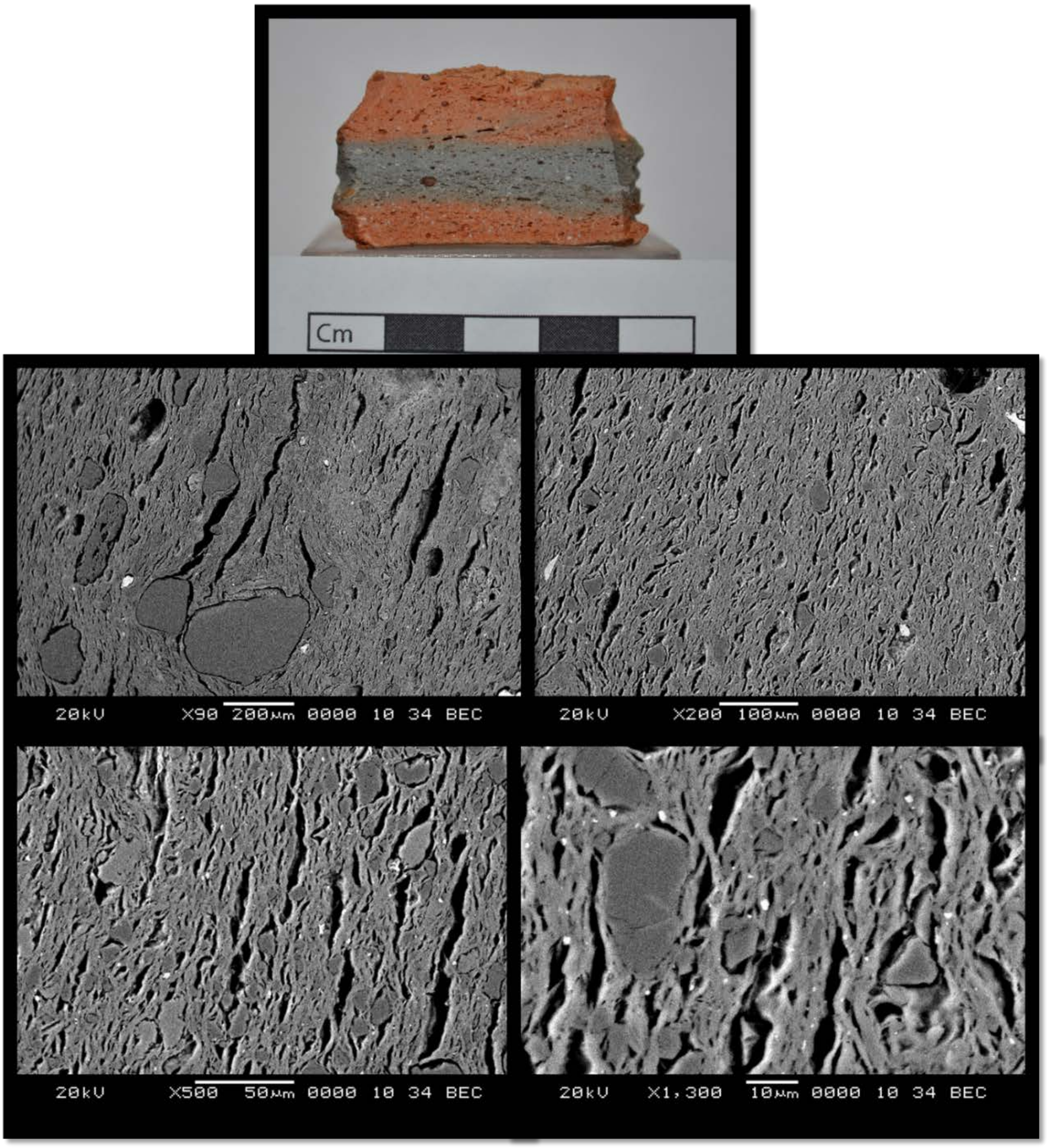


Figure C2. 6: Sample A6 in hand specimen and in SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: A7

Hand Specimen Description: A fine looking mid orange fabric, with a slightly dusty feel to it. Very few inclusions visible in hand specimen – a couple of what might be shell fragments, and rare large quartz crystals. Most notable are the moderately abundant large and very large pores, some longitudinal, some rounded, and some more distended, perhaps the result of bloating of the clay.

Thin Section Description: Mid orange fabric lacking large inclusions. Porosity far more apparent – very large angular spaces. Frequent small quartz and moderate/infrequent medium/large, sub angular, not very well sorted throughout the piece. Very occasional clay beads, cream. And iron oxide beads. Moderate longitudinal rounded pores.

SEM Description: A slightly unusual fabric, very different to 1, 2, and 3, the main ones. Infrequent large quartz and potassium feldspar, sub rounded/angular, 300-500 μm; abundant small and very small quartz and potassium feldspar, rounded to sub angular. Also some micas and calcareous inclusions/bone fragments, iron inclusions and anatase. Texture very closed in places, with moderately abundant small round pores giving a honeycomb-like texture.

Chemistry: Moderate Ca. Otherwise fairly middle of the line.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
A7	60.44	18.78	5.40	7.71	3.92	2.98	0.76

Fabric: Fabric 7

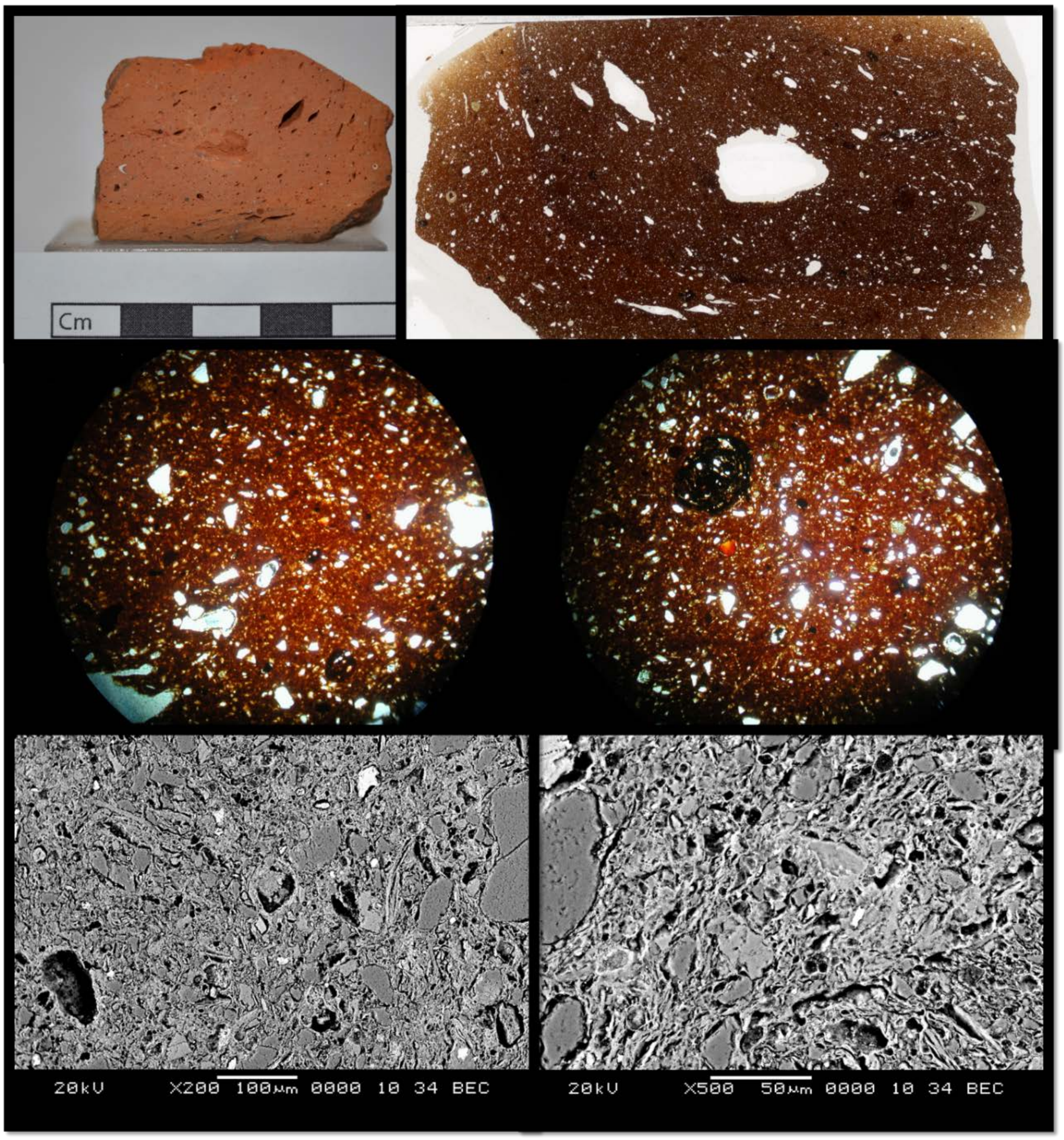


Figure C2. 7: Sample A7 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 200 and x 500 magnification.

Sample ID: A8

Hand Specimen Description: A relatively hard, sharp feeling mid to dark orange fabric, with few apparent inclusions – rare large quartz, and rare very large iron oxide beads. Some occasional small pores, generally slightly longitudinal, running east west. Could be remnants of burnt out shell, given shape?

Thin Section Description: Mid orange, but with large areas of clay streaks, paler and darker, iron rich. Also some very large dark red irony inclusions, plus usual spread of small rounded ones. Quartz in both large (infrequent-moderate) and small (very abundant), large often angular, small sub-angular and sub-rounded. Bimodal distribution again? Large not in clay streaky lumpy bits. Some sub angular pores.

SEM Description: Moderately frequent quite large rounded or sub rounded quartz inclusions, 100 – 300 µm, and frequent 40 – 70 µm sub angular or angular quartz, plus frequent smaller (c. 20 µm) quartz and potassium feldspar. Generally a very high proportion of quartz to clay. Also some occasional micas, and larger areas of iron rich clay, iron oxide inclusions, titanium dioxides. Platey clay minerals, with few small pores, but some very large, large, and medium sub rounded.

Chemistry: Low Ca. Low Ti. High Fe.

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
A8	65.57	20.08	0.59	8.09	3.71	1.41	0.54

Fabric: Fabric 1

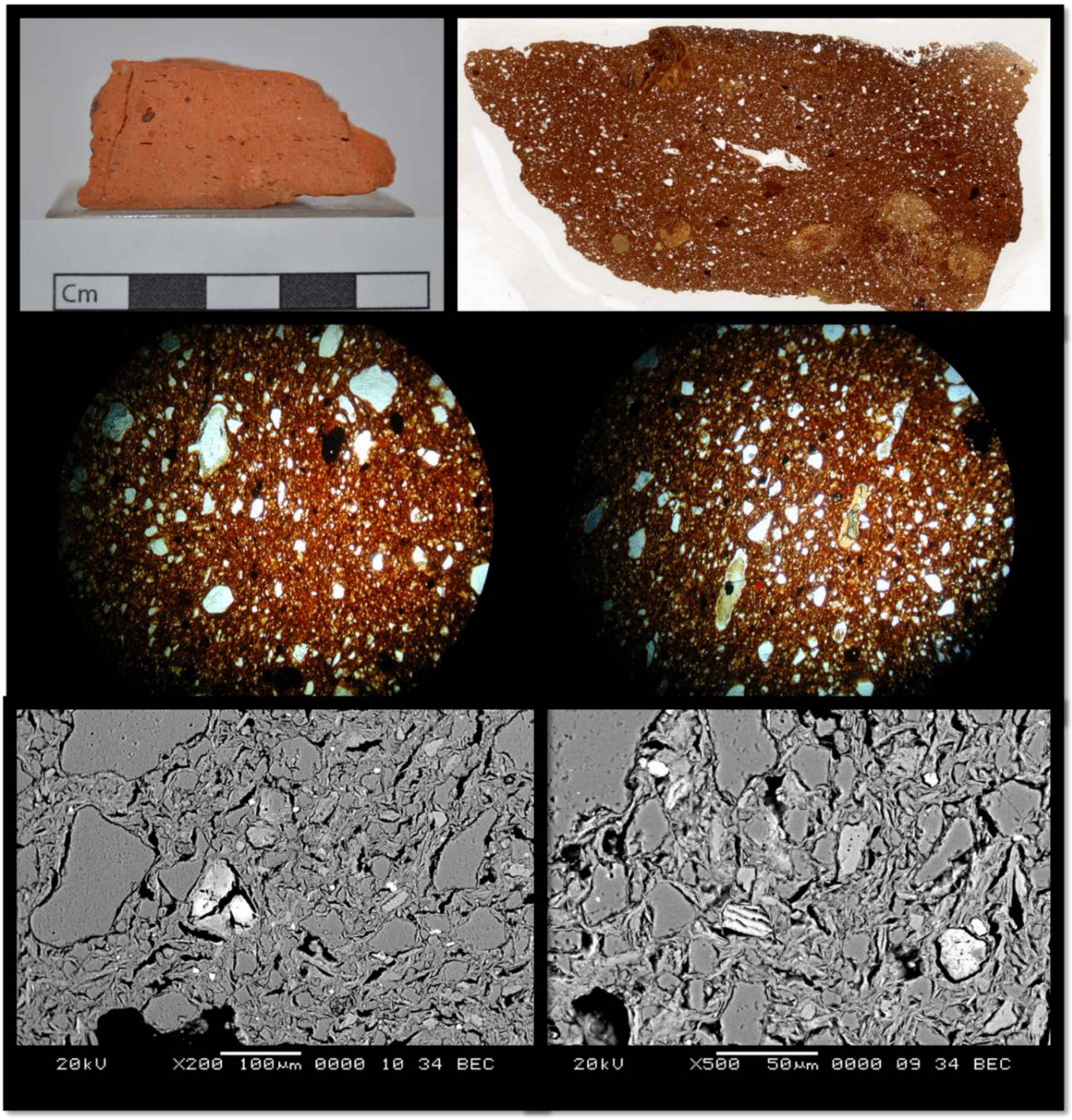


Figure C2. 8: Sample A8 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 200 and x 500 magnification.

Sample ID: (G)A9

Hand Specimen Description: A hard feeling, busy looking fabric, with a mid-orange outer and light bluish grey core. Quite frequent large quartz crystals evenly spread throughout the sherd, and occasional very large rounded pores, as if a very large inclusion has been present (removed either during firing or during polishing?).

Thin Section Description: N/A

SEM Description: Fabric characterised by moderately abundant large quartz inclusions, generally sub rounded, up to c. 200 - 500 µm. Large regions of iron rich clay of similar size. Quite empty in terms of the middle size fraction, but moderately abundant small, up to c. 20 µm, generally sub rounded. Some heavy inclusions, but not particularly apparent. Clay body somewhat vitrified, starting to interact with smaller quartz, and showing lots of small vitrification bubbles 1 or 2 µm. Otherwise piece has moderately abundant large and very large rounded pores (as A8), and some large longitudinal pores/cracks cause by clay shrinkage.

Chemistry: 3rd highest Al. Rest middling.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
GA9	63.18	22.87	0.69	6.96	4.00	1.43	0.86

Fabric: Fabric 1

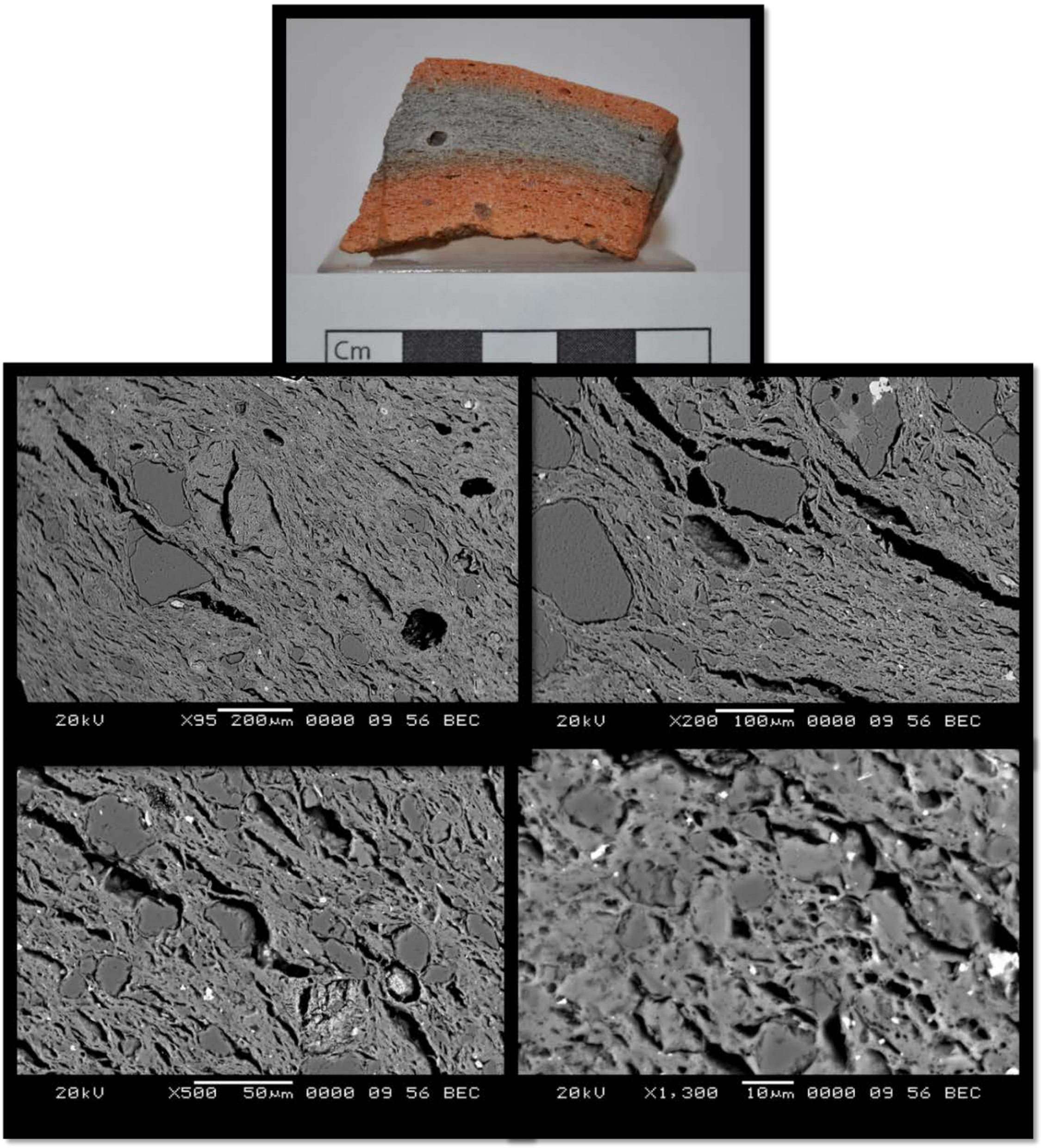


Figure C2. 9: Sample A9 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: B1

Hand Specimen Description: A slightly brittle, hard, fine fabric, characterised by very few visible inclusions, besides two or three very large clay beads, in cream and dark greyish red clays. Most notable about the fabric are the frequent large round and ovular pores.

Thin Section Description: Mid orange, slightly darker than As. Far fewer inclusions apparent, being dominated by moderately frequent very small sub angular/sub rounded quartz. Cluster of large quartz on one surface (presumably bottom, linked to sanding to help release from mould/work bench. A few large pale yellowish cream and dark reddish black spots, clay beads and iron rich lumps. Moderately frequent large sub-rounded pores.

SEM Description: A fabric with very rare large inclusions, just occasional angular quartz grains c. 400 µm in diameter, but frequent medium and small, 20 – 60 µm, generally sub angular or sub rounded, well sorted, and with occasional potassium feldspar of the same size and shape range. Occasional micas, and heavy inclusions including iron and titanium oxides. Clay matrix appears somewhat platey, but with reasonably high sintering, and signs of the beginning of vitrification between individual clay minerals. Some large rounded pores, up to c. 500 µm across, but very few at the small scale, with clay minerals and inclusions closely sintered into a continuous surface (possibly the cause of the large pores).

Chemistry: Quite high Mg. Second lowest Al. Low end for Ca. Mid for most other things, quite high Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
B1	67.69	16.62	1.01	6.99	3.69	2.92	1.07

Fabric: Fabric 3

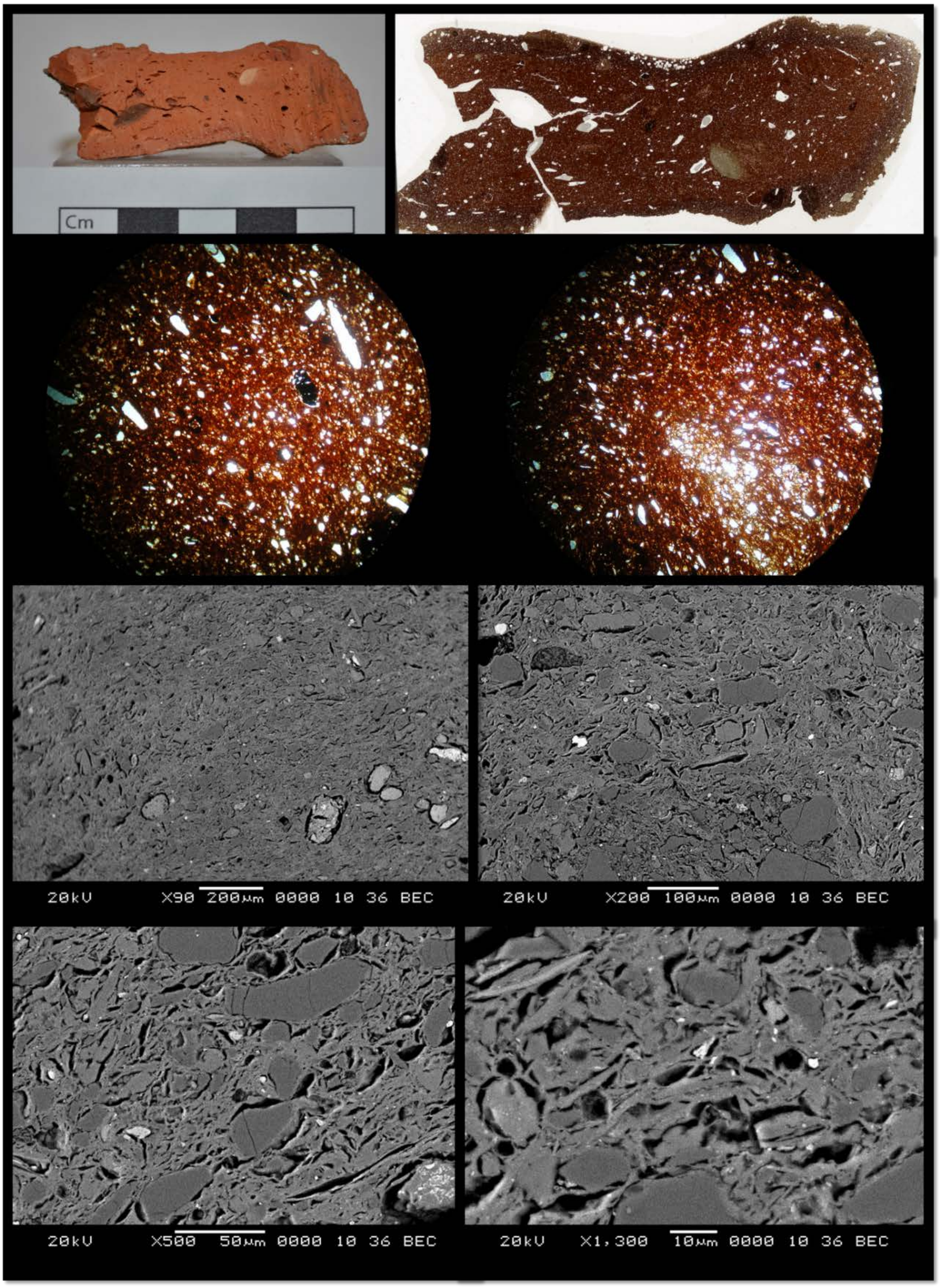


Figure C2. 10: Sample B1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: B2

Hand Specimen Description: A hard feeling fabric, slightly coarse to touch on account of the frequent rounded pores. Large quartz inclusions also apparent, moderately abundant and unevenly spread through the matrix. Occasional iron oxide beads, cream clay beads, and streaks of paler clay are also seen.

Thin Section Description: N/A

SEM Description: Quite abundant very large quartz inclusions, rounded, between 200 µm and 600 µm in diameter. Clay beads of same size, shape, frequency, and sortedness. Beneath this is a highly abundant small quartz fraction, 20 – 50 µm, generally sub angular. Rare potassium feldspar, angular, of a middle size range (up to about 100 µm). Quite frequent iron, both in clay beads, and occasional iron oxide inclusions, small. Texture divided between two main types, one very continuous, highly sintered or even vitrified into an a-porous surface, one quite holey, vitrified, but with clay minerals shrinking away from each other to leave small angular pores. Seems to be in areas with more frequent silt-sized quartz inclusions.

Chemistry: Middling in everything.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
B2	66.85	19.06	0.63	7.46	3.47	1.51	1.02

Fabric: Fabric 2

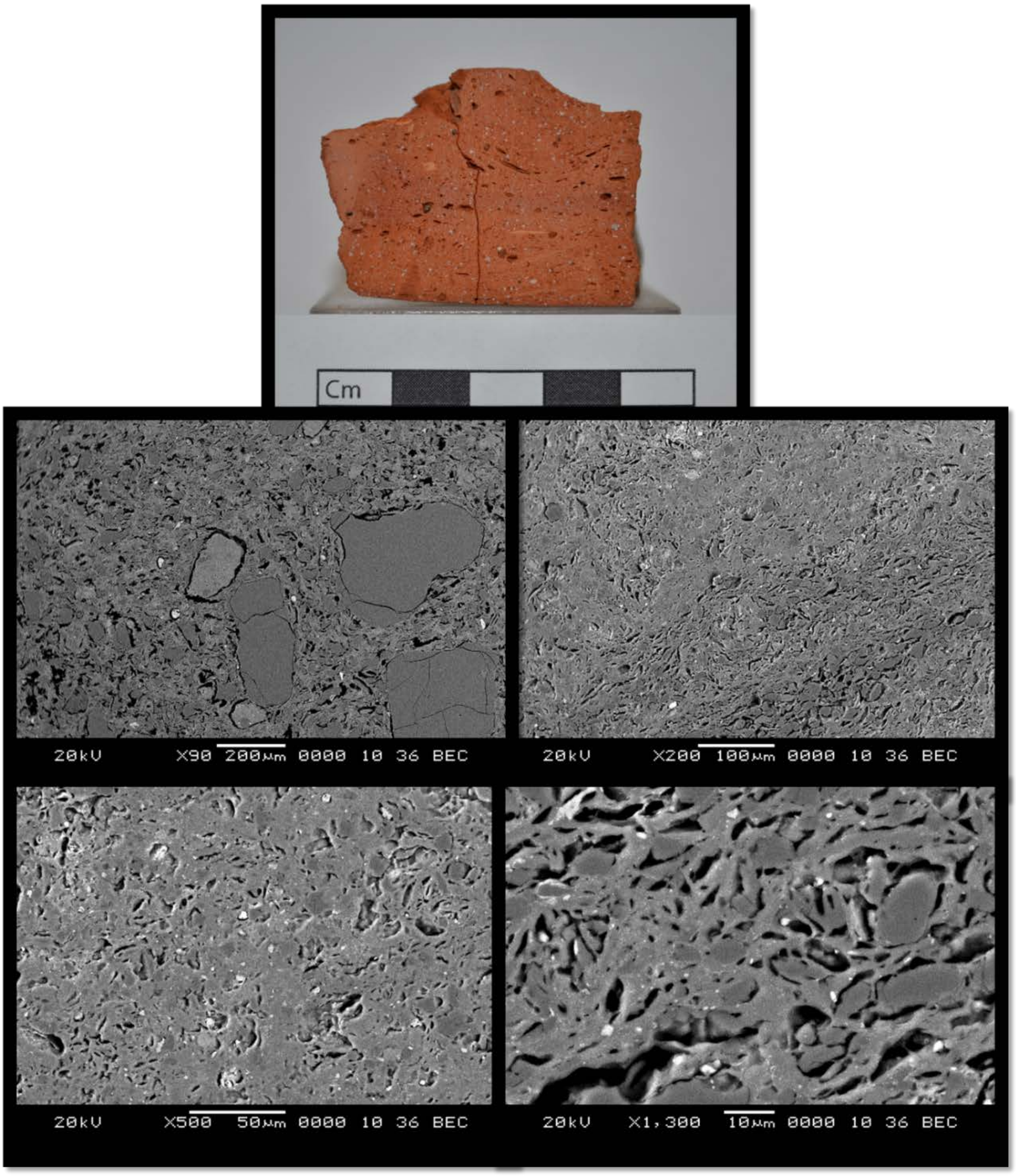


Figure C2. 11: Sample B2 in hand specimen and in SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: B3

Hand Specimen Description: A dark – mid red hard, smooth looking fabric, with occasional large quartz inclusions, one or two narrow streaks of lighter coloured clay, and moderately abundant small round pores and two much larger angular voids, perhaps created by the clay being poorly pressed into the *tegula* mould.

Thin Section Description: Very stratified smears of different clay colour, mid orange body but large bits of cream and darker red. Not apparent in hand specimen. Dominated by small quartz again, but this time more large quartz, also large sub rounded pores. Large quartz again concentrated towards one surface. Quartz of any size mostly absent from some of the smears, but apparent (even concentrated) into others, particularly cream ones, something seen in other pieces. Some smaller rounded black red iron dots.

SEM Description: Quite similar to B2, with occasional very large rounded quartz inclusions (generally concentrated near surfaces) between 200 and 600 μm, with iron rich clay beads of similar shape and size. Occasional medium quartz inclusions, sub angular, around 50 μm, but dominant inclusion fraction is small, max 20 μm, generally rounded. Similar texture differences to B2, above, with some areas showing a very continuous vitrified surface, whilst others have lots of shrinkage of clay away from inclusions. Clear from x18 image that these reflect streaks of different clays, poorly mixed together.

Chemistry: Quite high Si (and somewhat low Al). Low Ca.

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
B3	68.69	18.73	0.31	7.23	3.17	1.24	0.63

Fabric: Fabric 2

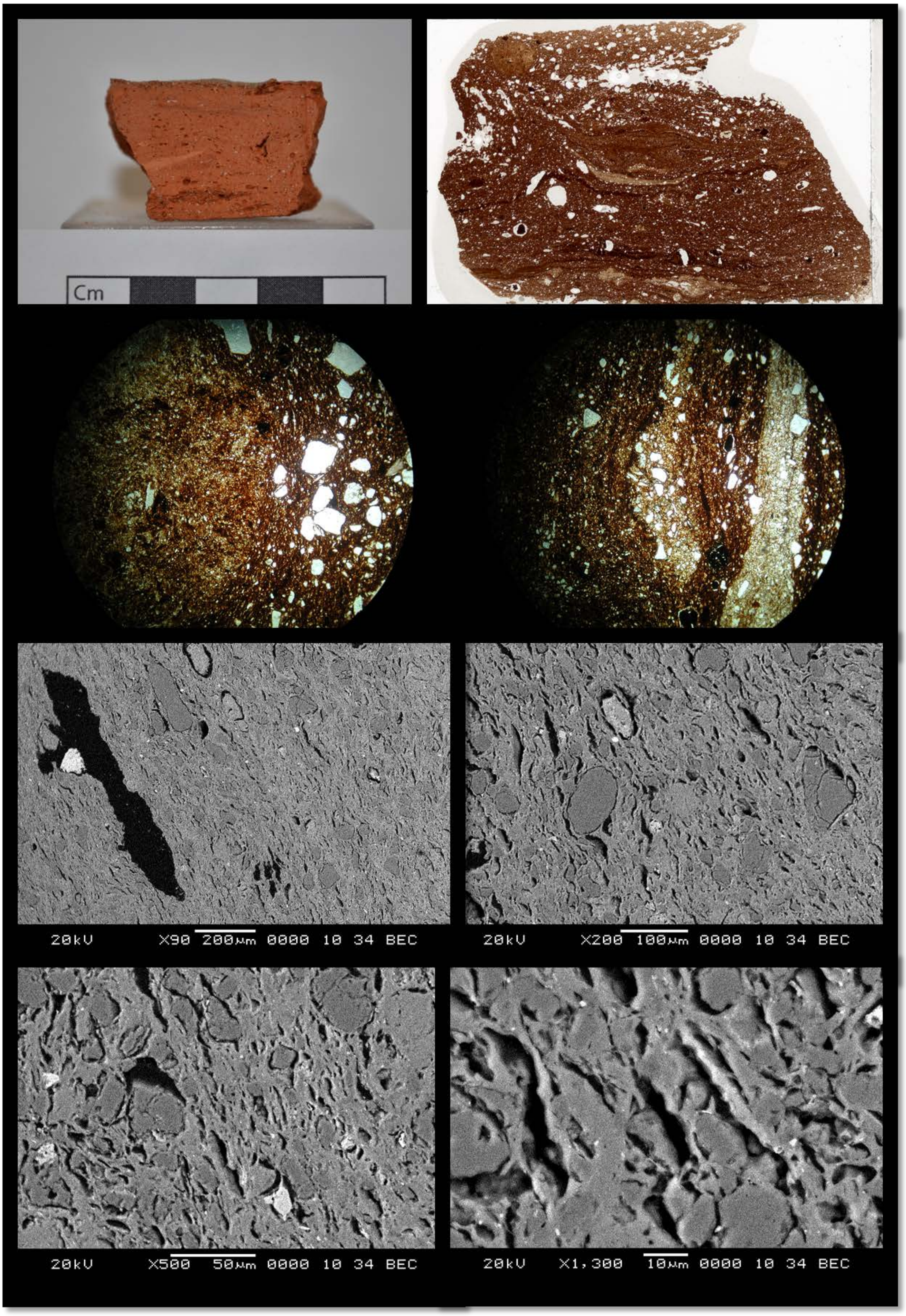


Figure C2. 12: Sample B3 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: B4

Hand Specimen Description: A dark orangey red fabric, again quite brittle feeling (like B1), having cracked during sawing. Very few inclusions visible, besides a moderate spread on the bottom edge of the piece. Several large angular voids exist, together with large extended pores and frequent small round inclusions. Occasional large clay beads are visible in a darker red clay.

Thin Section Description: N/A

SEM Description: Moderately abundant large, slightly angular quartz inclusions, 200-300 µm, and abundant small, up to 30 µm sub angular quartz. Some iron oxides, mainly as clay beads, but also some discrete inclusions. Very occasional potassium feldspar, same fraction as small quartz. Generally quite a smooth texture, with clay minerals highly sintered, towards vitrified into continuous surfaces, but with quite frequent shrinkage pores.

Chemistry: Low Ca. Quite high Fe and Mg.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
B4	64.26	19.52	0.42	7.99	4.04	3.10	0.67

Fabric: Fabric 2

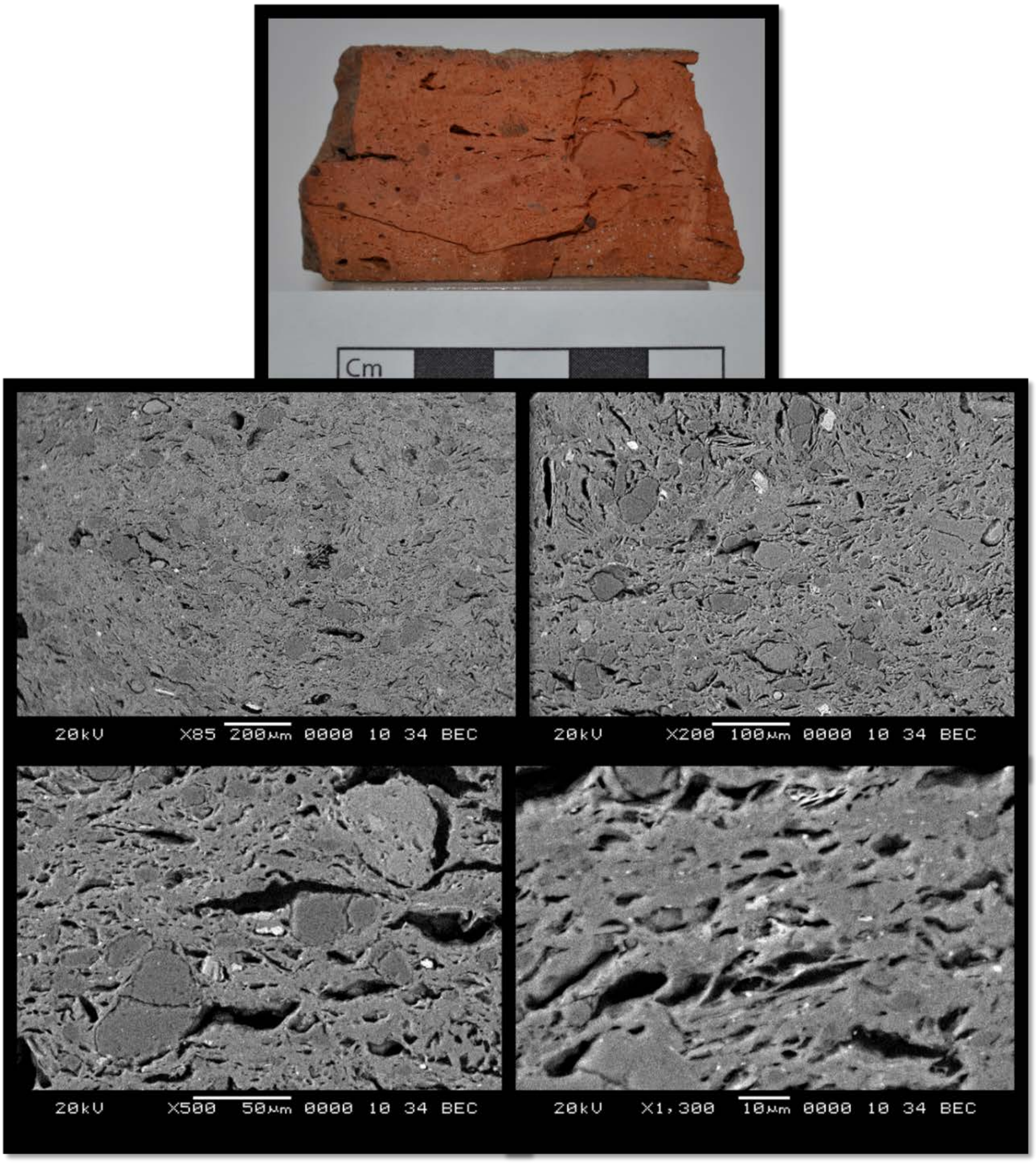


Figure C2. 13: Sample B4 in hand specimen and in SEM backscatter micrographs at x 85, x 200, x 500, and x 1300 magnification.

Sample ID: B5

Hand Specimen Description: A smooth, fine looking fabric, with few visible quartz inclusions, very occasional quite small red clay beads, and one or two possible shell fragments. The main feature of the fabric are large subrounded or subangular voids or pores, plus smaller rounded pores.

Thin Section Description: Mid orange fabric, with very few large inclusions or features, besides very large sub rounded pores. Very few large quartz inclusions (with cluster on one surface, from sanding), but moderately abundant small sub angular. Occasional small clay streaks, and usual moderate abundance of small round iron oxide.

SEM Description: Practically no large inclusions at all. Largest are some iron oxide framboids at about 30 µm, with abundant sub rounded quartz fraction up to about 20 µm, and frequent potassium feldspar, and some micas. Busy, with high inclusion to clay proportions, but forms a relatively continuous surface, clay minerals starting to vitrify, but with some plateyness remaining and longitudinal shrinkage pores. Regions of small very round pores, up to about 10 µm diameter.

Chemistry: 3rd highest Mg. Otherwise middling. Lowish Ca. Highish K. (to go with Mg?)

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
B5	64.09	19.53	1.25	6.77	4.16	3.23	0.98

Fabric: Fabric 3

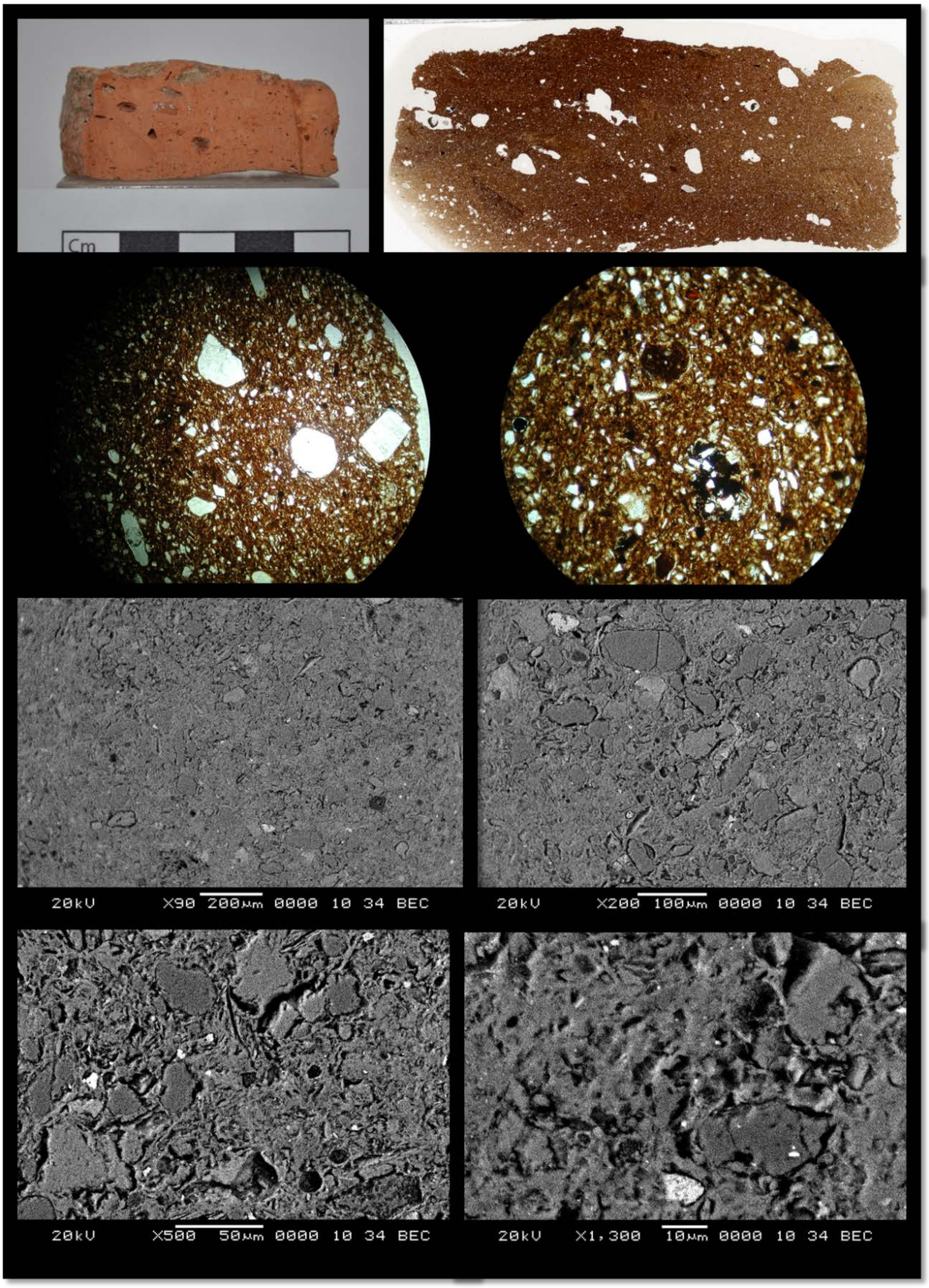


Figure C2. 14: Sample B5 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 and x 100 magnification, and SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: B6

Hand Specimen Description: A very clean mid orange fabric, with a very smooth feel. Very few visible inclusions or clay variations, just some rounded pores and slightly extended pores.

Thin Section Description: Mid orange, again mod abundant very small quartz (sub round?), and very few large sub ang, concentrated to one edge. Usual proportion of streaky clay, and iron oxide in small and large. Large round pores.

SEM Description: Again very few large inclusions, except some very large quartz near to one edge, rounded, up 400-500 µm, and one or two large framboids, 100 – 200 µm. Otherwise dominant quartz fraction, sub rounded, with abundant potassium feldspar mixed in, occasional mica, and frequent small very round pores. Moderately sintered, towards vitrified clay minerals, but locked closely together.

Chemistry: Highish Mg. Lowish Ca. Quite high Ti.

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
B6	65.82	18.67	1.21	6.64	3.65	2.90	1.10

Fabric: Fabric 3

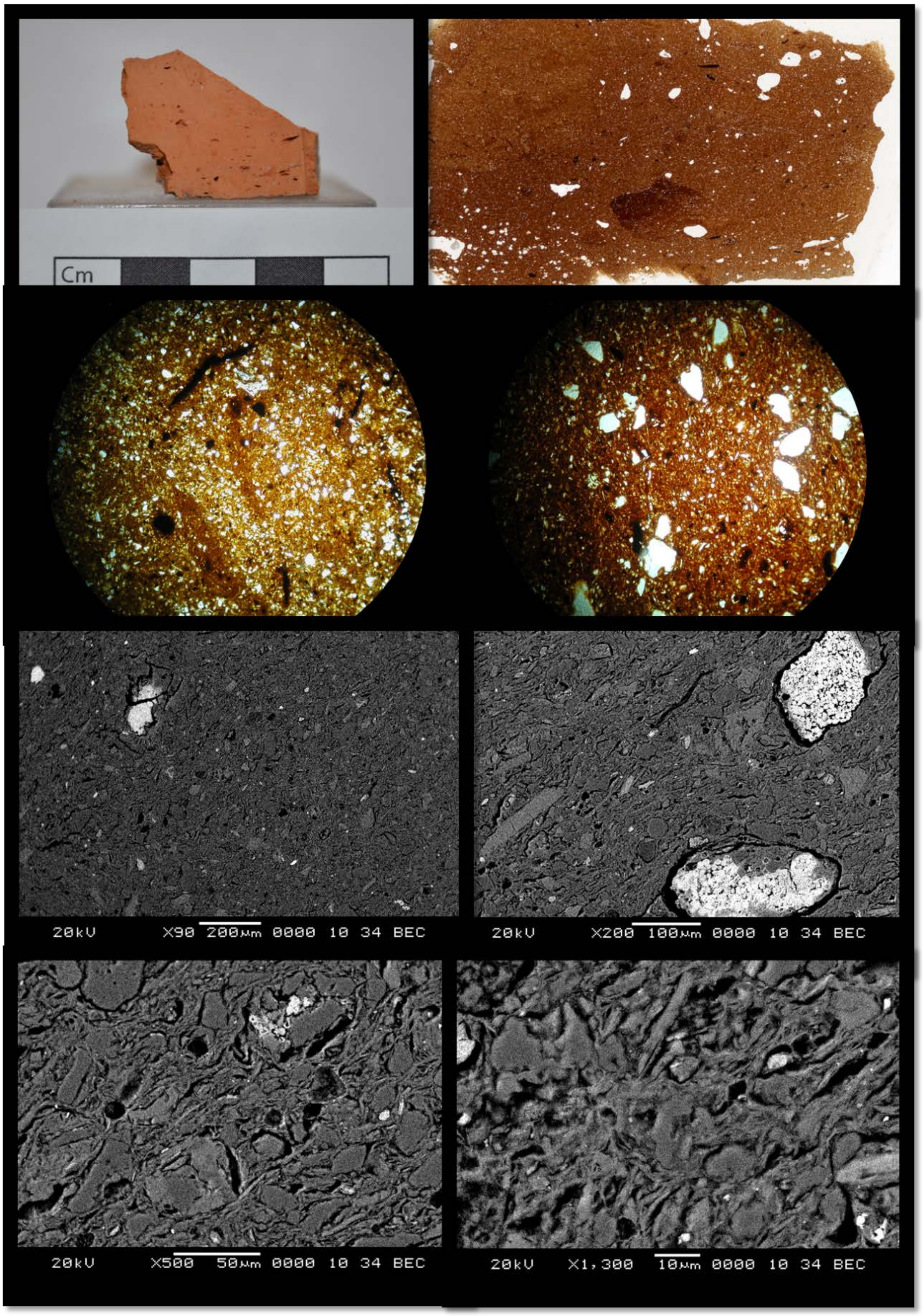


Figure C2. 15: Sample B6 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 and x 100 magnification, and SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: E1

Hand Specimen Description: A very hard fabric, with thin skin of dark brownish black, and a brownish red body, with a thin streak of bluish black in the very centre. Large milky quartz crystals visible spread throughout, along with several cream coloured round clay beads. Very hard, sharp feel.

Thin Section Description: Moderately abundant large quartz, generally angular, plus mod. abundant small rounded quartz. Occasional very large, plus more frequent large and medium iron oxide beads. One huge one. Frequent huge pores, large voids, often with very irregular shapes/edges. Horizon of less sandy clay through middle, suggest temper?

SEM Description: Quite abundant very large quartz, up to about 500 µm, but general between 100 and 200 µm, generally sub rounded, often cracked. Quite rare small quartz, between 30 and 50 µm, also often cracked, sub rounded. Some large angular iron inclusions, and rounded clay beads made from ‘lighter’ (i.e. darker) chemistry. Occasional degrading potassium feldspar, large and angular. Texture highly vitrified, smooth looking with no individual clay minerals apparent. Frequent sub rounded pores.

Chemistry: Low Mg. Second highest Si. Low Ca. Second lowest Fe.

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
E1	70.45	18.29	0.25	5.09	3.98	1.11	0.83

Fabric: Fabric 5

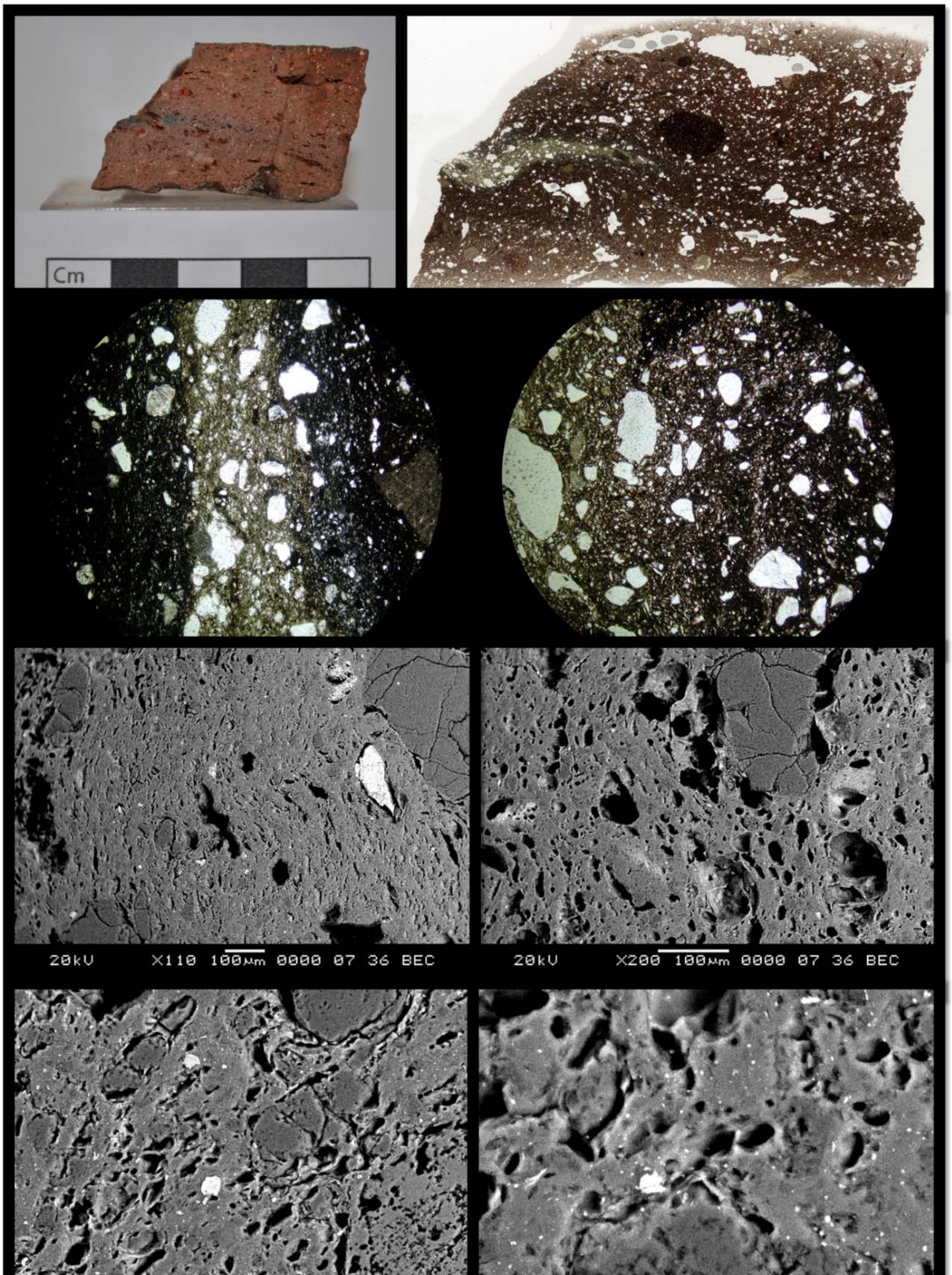


Figure C2. 16: Sample E1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 110, x 200, x 500, and x 1300 magnification.

Sample ID: J1

Hand Specimen Description: Light pinkish brown, quite soft fabric, with few mineral inclusions visible but angular streaks and lumps of slightly different coloured clay, possibly grog, with long cracks and pores running through texture.

Thin Section Description: Fabric lacking in large crystalline inclusions, but large clay-formed inclusions, possibly grog on account of angularity. Fabric otherwise reasonably homogeneous, occasional larger irony lump, slightly swirled in. But otherwise dotted with small sub angular and sub rounded quartz. Grog – two types? One with lighter matrix and frequent small-medium angular quartz. (734 and 739/40). Other laminated clay? (733 and 730). 739/40 one very different from bulk fabric, so grog from different ceramic? Several very large voids across section. Also some small pores, generally round.

SEM Description: Very rare large quartz inclusions, up to c. 200 µm, but otherwise very few mineral inclusions visible. Just a very honeycomby clay matrix, formed of vitrified, continuously connected clay. Plus occasional very large, up to 2 mm, grog pieces, angular corners, similar clay to body. Occasional very large sub rounded pores.

Chemistry: Quite high Al. Quite low Si. High Ca.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
J1	55.26	20.56	10.58	7.03	3.95	1.89	0.72

Fabric: Fabric 8

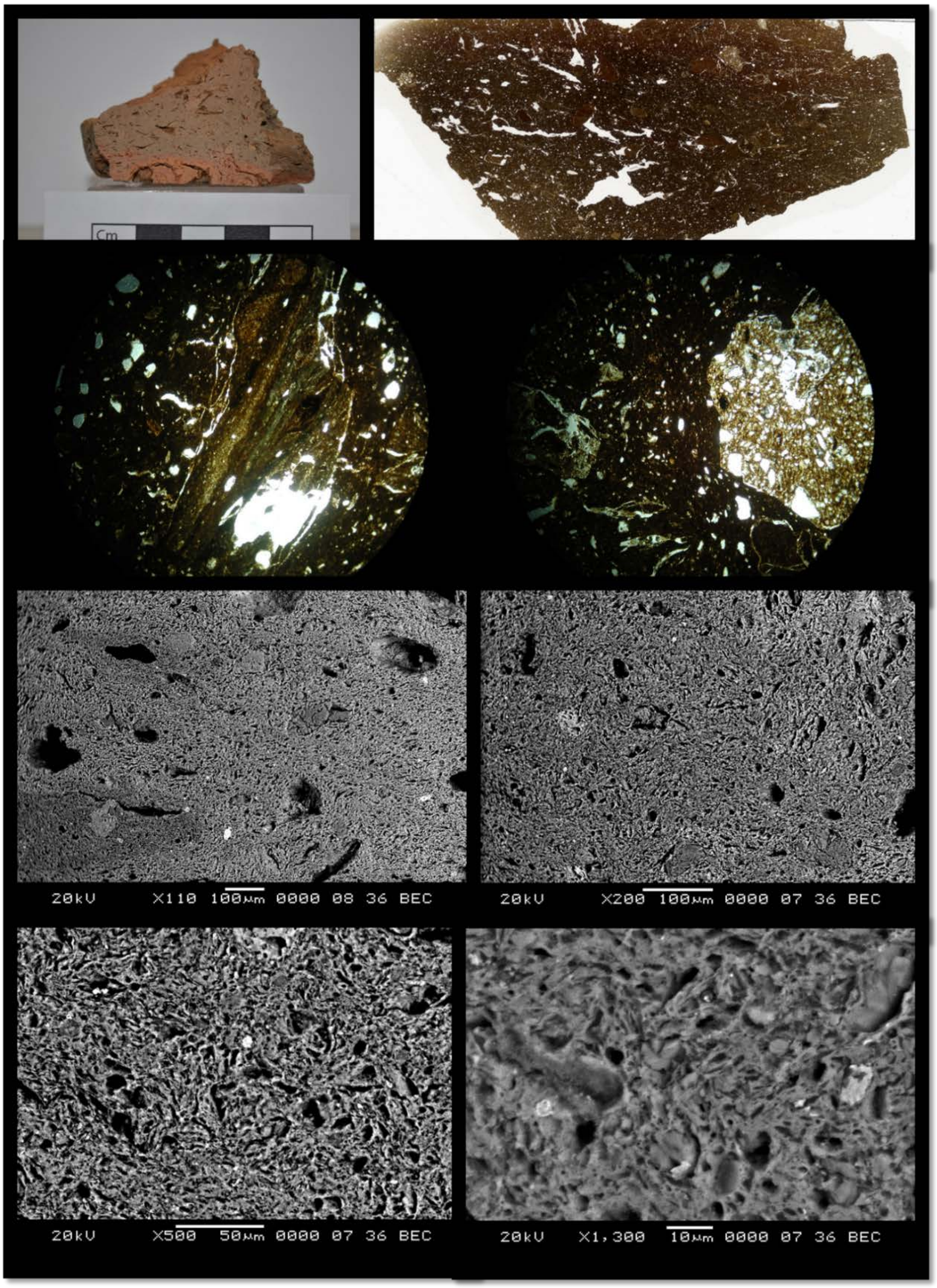


Figure C2. 17: Sample J1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 110, x 200, x 500, and x 1300 magnification.

Sample ID: M1

Hand Specimen Description: A slightly soft, powdery, fabric, brownish yellow in colour, with glittery mica grains very apparent. Lumpy, friable fractures.

Thin Section Description: In thin section highly abundant small sub angular quartz, plus occasional mica grains (muscovite), same sort of size fraction. Often orientated same direction as each other. Generally low porosity, except larger angular pores, voids in clay caused by shrinkage?

SEM Description: Moderately abundant, well-sorted, large quartz and mica (up to 100 µm), with occasional iron rich clay beads or framboids. Clay fabric clearly very soft, showing significant polishing artefacts/grains ripped out, and remains platey, sintered, but not particularly vitrified.

Chemistry: Third highest Si. Non calc. Third lowest Fe.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
M1	69.11	18.22	1.86	5.18	3.39	1.25	0.99

Fabric: Indiv.

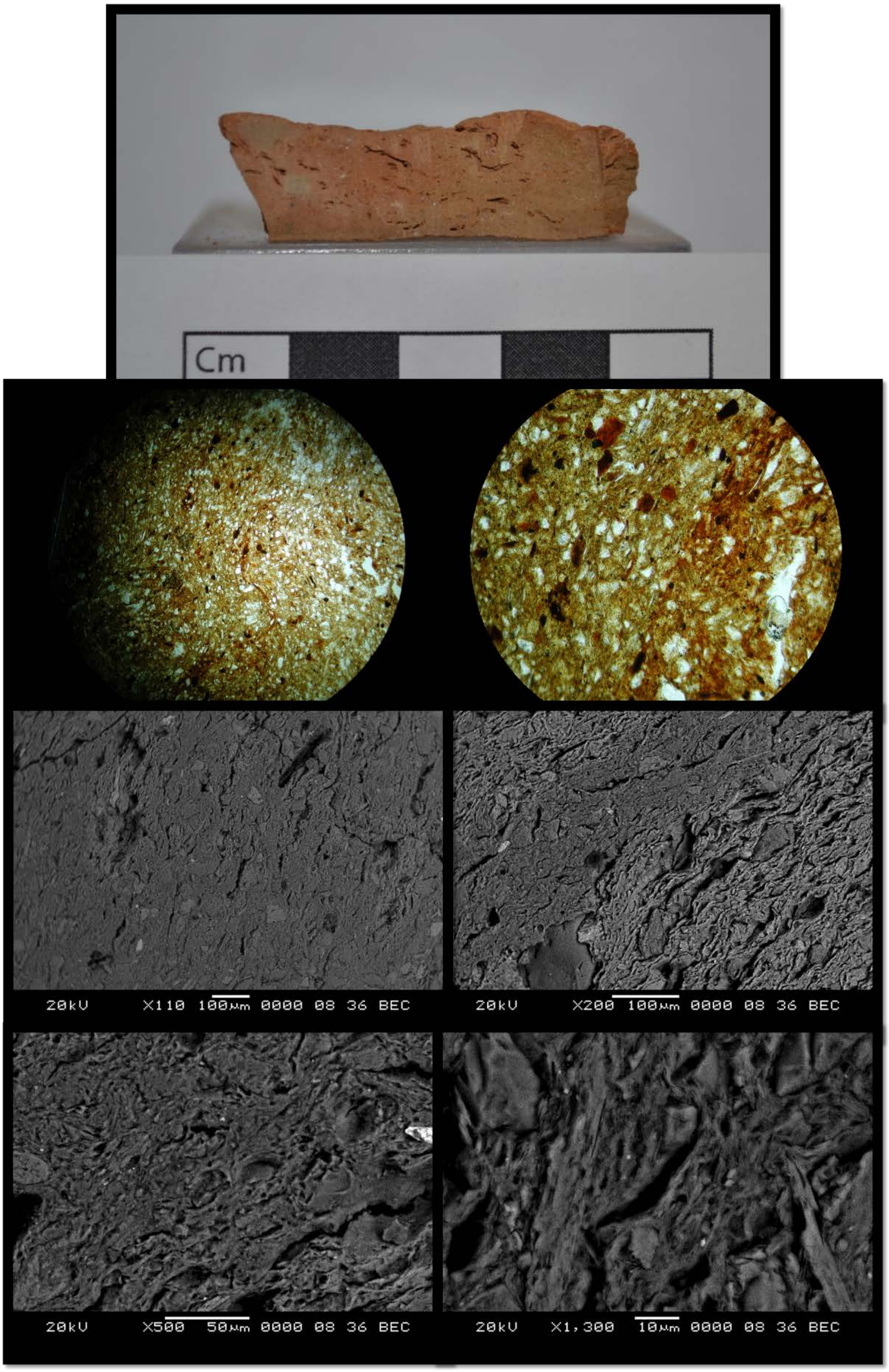


Figure C2. 18: Sample M1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 and x 100 magnification, and SEM backscatter micrographs at x 110, x 200, x 500, and x 1300 magnification.

Sample ID: P1

Hand Specimen Description: A hard, sharp feeling fabric, mid orange in colour (with a slightly brownish orange outer skin), with occasional large quartz inclusions visible, and large shrinkage cracks, due to being a sample from a flange where the clay was folded.

Thin Section Description: N/A

SEM Description: Moderately abundant very large sub rounded and sub angular quartz, 100 - 500 µm, along with large iron rich clay beads. Medium quartz fraction, quite rare, c. 50 µm, sub rounded. Some quartz cracked from heat. Occasional small rounded, 10 µm, starting to vitrify into clay body. Clay body shows remains of platey texture, but highly sintered and vitrifying. Some very large rounded pores, and small longitudinal pores where the body is less closed.

Chemistry: Very low Ca.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
P1	67.37	19.37	0.19	6.69	4.09	1.38	0.91

Fabric: Fabric 1

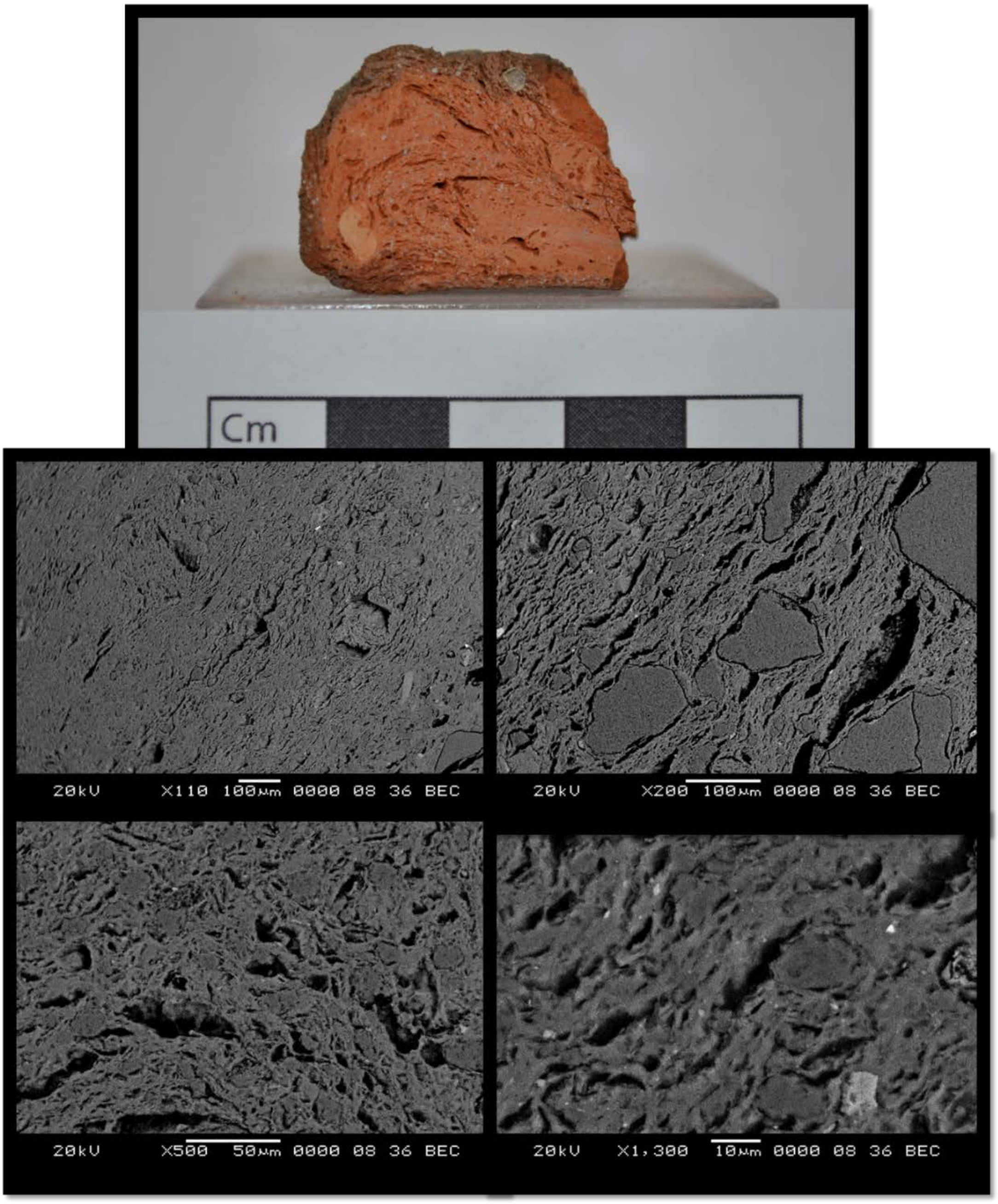


Figure C2. 19: Sample P1 in hand specimen and in SEM backscatter micrographs at x 110, x 200, x 500, and x 1300 magnification.

Sample ID: X1

Hand Specimen Description: Mid orange outer, bluish grey core, abundant quartz sand inclusions. Some longitudinal pores, and occasional large iron clay beads.

Thin Section Description: Fabric with relatively abundant, well sorted large sub angular and sub rounded quartz crystals, and relatively frequent medium and large iron oxide inclusions. Many small longitudinal pores, aligned east-west, as if from shrinkage during firing, plus some larger longitudinal or sub longitudinal pores on same orientation.

SEM Description: Frequent large and very large pores, generally rounded, up to 2 μm across, but often 50 – 100 μm, with some longitudinal character. Also quite abundant large sub rounded and sub angular quartz, 100 – 200 μm, often cracked, and small sub rounded c. 10 μm quartz. Regions of highly iron rich clay, and frequent large irony clay beads. Occasional potassium feldspar of same size fraction. Clay platey, longitudinally arranged, showing reasonably high sintering, but lots of gaps between clay minerals.

Chemistry: Slightly high Si. Non calcareous. Lower end of Fe. Otherwise not very interesting!

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
X1	68.07	19.35	0.63	6.07	3.69	1.23	0.95

Fabric: Fabric 1

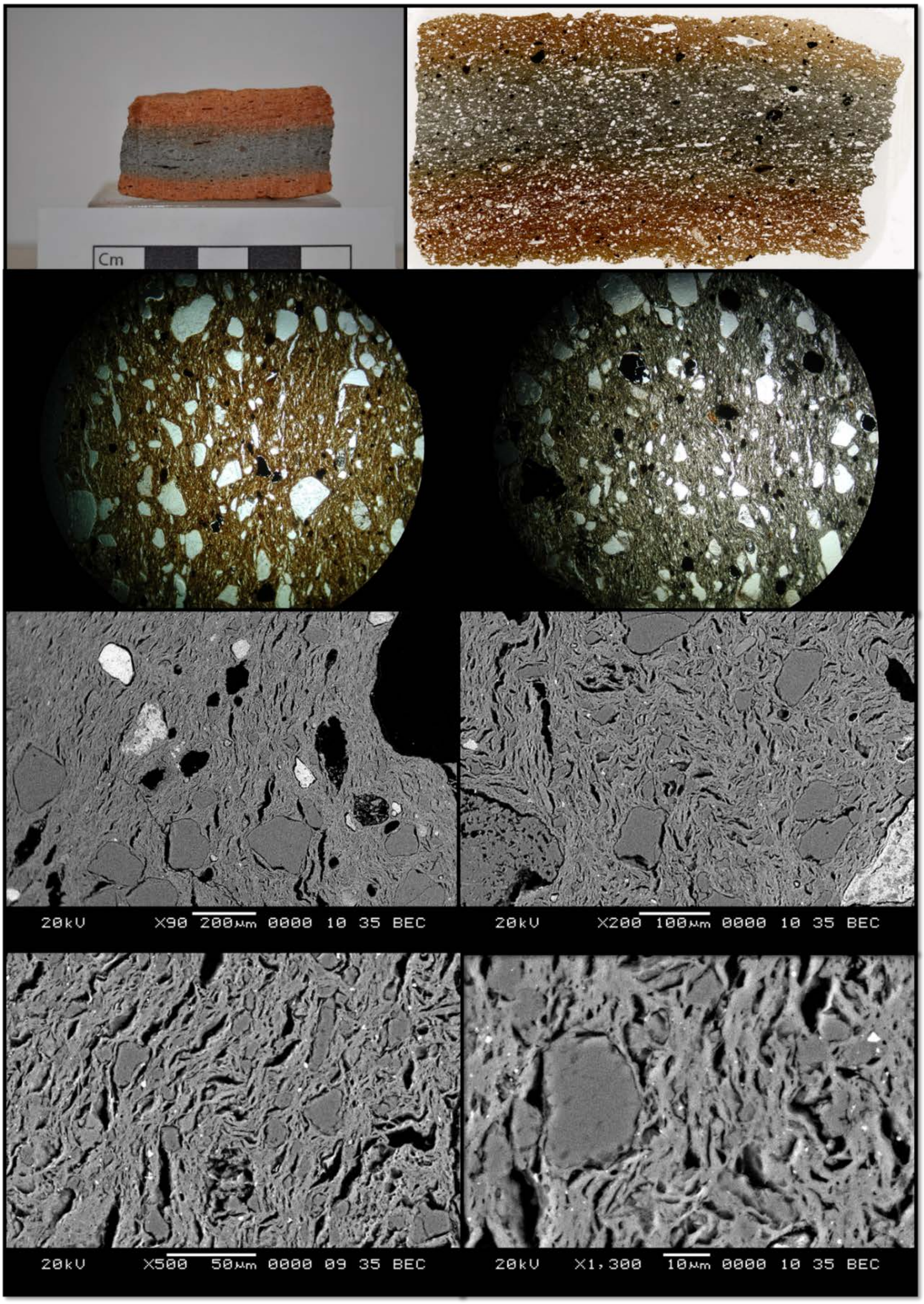


Figure C2. 20: Sample X1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: X2

Hand Specimen Description: Dark reddish orange outer and a bluish grey core, not dissimilar to X1. Quite sandy, with occasional iron rich beads, and large pale rock fragments. Hard, highly fired, with a sharp fracture. Appears quite porous, with longitudinal shrinkage cracks throughout.

Thin Section Description: N/A

SEM Description: Moderately abundant very large rounded quartz, up to 6 or 700 µm, with occasional potassium feldspar mixed in, and large iron rich regions. Smaller size fraction of medium quartz, 30 – 50 µm, sub angular and sub rounded, and small fraction, 10 µm. Clay body quite highly fired, smooth continuous surface in places, others quite porous with gaps between clay minerals, caused by shrinkage, longitudinal.

Chemistry: Quite high Al, Fe (4th highest), lowest Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
X2	64.45	21.04	0.37	8.34	3.97	1.58	0.23

Fabric: Fabric 1

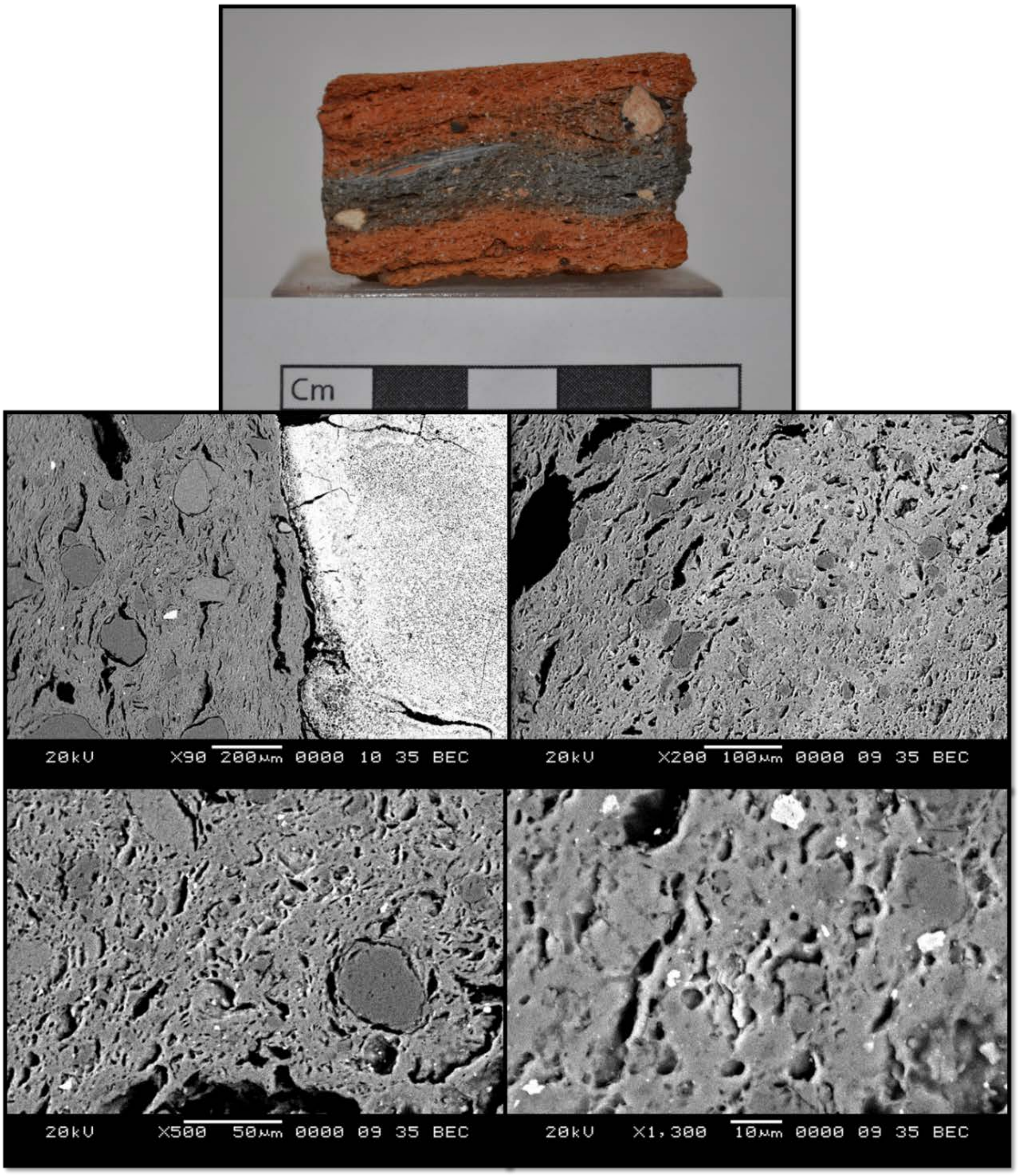


Figure C2. 21: Sample X2 in hand specimen and in SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: 3152.1

Hand Specimen Description: A fine, moderately hard fabric with a pinkish orange exterior and a pale orangey grey, then dark blackish grey core. Some large quartz inclusions are visible, but more notable are the very large angular grog inclusions, and large pores, possibly left by grog inclusions ripped out by the saw.

Thin Section Description: N/A

SEM Description: Very few large mineral inclusions are visible, with just the occasional very large (500 µm) quartz, sub rounded and cracked. The dominant inclusion fraction is between 50 and 100 µm, consisting of both quartz and potassium feldspar, sub rounded, quite well sorted throughout, and beneath this abundant small quartz (c. 10 µm), angular, and micas, and iron and titanium oxides. Very large angular grog pieces are seen across the sample, sometimes in very similar clay to the main body, sometimes in somewhat different clays. The clay body is quite highly vitrified, clay minerals joined into continuous liquid phases, with many small round pores across the sherd.

Chemistry: 4th lowest Si. 4th highest Ca.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3152.1	57.35	19.26	10.94	6.10	3.49	2.03	0.82

Fabric: Fabric 8

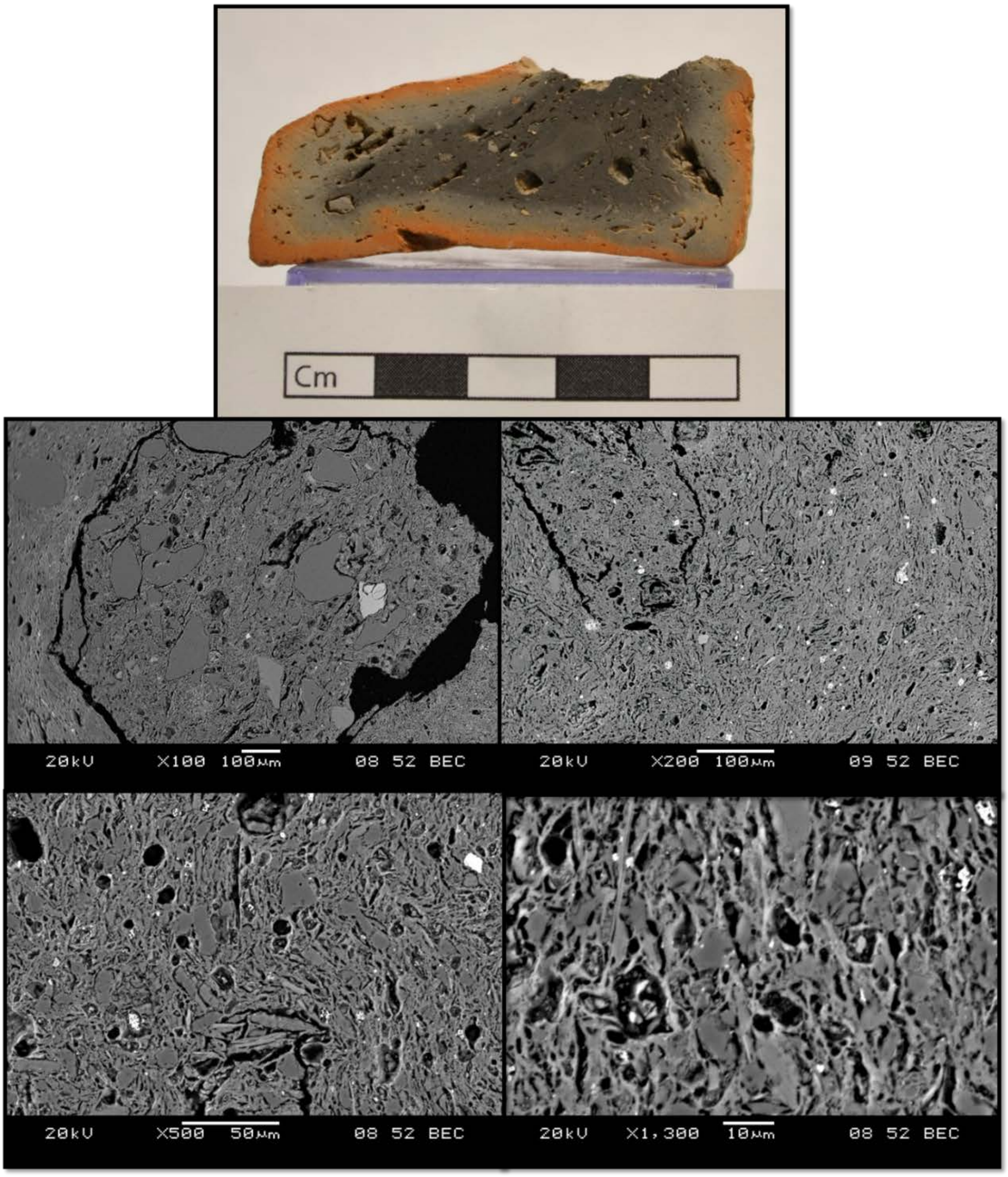


Figure C2. 22: Sample 3152.1 in hand specimen and in SEM backscatter micrographs at x 100, x 200, x 500, and x 1300 magnification.

Sample ID: 3152.2

Hand Specimen Description: A mid brownish orange slightly soft, friable fabric, with occasional visible very large inclusions, rare small clay beads, and occasional rounded pores.

Thin Section Description: N/A

SEM Description: Occasional very large quartz crystals, between 200 and 700 µm, sub angular and sub rounded, with rare potassium feldspar in the same range (one example showing a crystal growth rim). Beneath these, very angular quartz (often with perfect crystal angles seen), between 50 and 100 µm, and then abundant small rounded quartz, micas, potassium feldspar, and framboidal iron beads. Clay matrix generally forms into complete continuous surfaces, very highly sintered, but not particularly highly vitrified. Frequent small (and occasional very large) round pores are seen.

Chemistry: Low Si. Ca heading up a bit. Highest Fe. Reasonably high Mg and Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3152.2	59.51	19.40	4.43	9.14	3.52	2.92	1.08

Fabric: Fabric 7

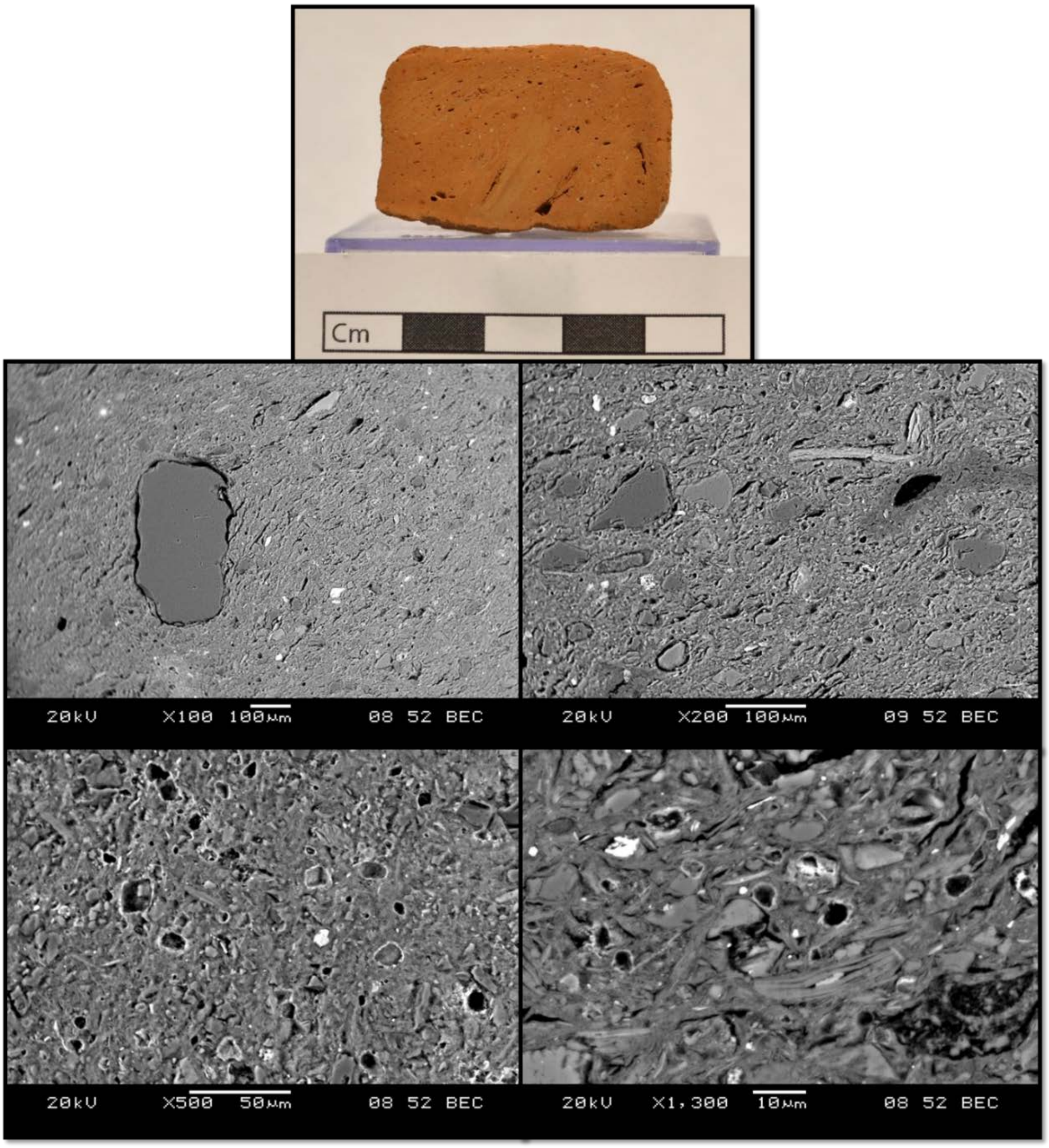


Figure C2. 23: Sample 3152.2 in hand specimen and in SEM backscatter micrographs at x 100, x 200, x 500, and x 1300 magnification.

Sample ID: 3152.3

Hand Specimen Description: A dark orange fabric, slightly soft, with moderately abundant large quartz inclusions and occasional creamy coloured round clay beads. Quartz predominates in the centre of the piece. Moderate porosity, including both longitudinal and large rounded pores.

Thin Section Description: N/A

SEM Description: A fabric exhibiting a clear bimodal inclusion split – moderately abundant very large angular, sub angular, and sub rounded quartz, 200 – 600 μm in diameter, with occasional potassium feldspar of the same shape and size, and occasional clay beads and iron rich clay beads of the same size, generally rounded. This is in contrast to the smaller inclusion fraction, between 5 and 50 μm, made up of abundant angular quartz crystals, iron oxides, micas, potassium feldspars, and titanium dioxides. This mineral fraction is highly mixed, with varying orientations, sizes, and shapes, almost appearing detrital. The clay matrix is smooth, highly sintered, and slightly vitrified, with some longitudinal pores remaining caused by shrinkage of the clay minerals. Otherwise pores are very large and sub rounded.

Chemistry: Nothing much to say. Middling for all, lowish K and Mg.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3152.3	66.77	19.72	1.33	7.37	2.83	1.24	0.73

Fabric: Indiv.

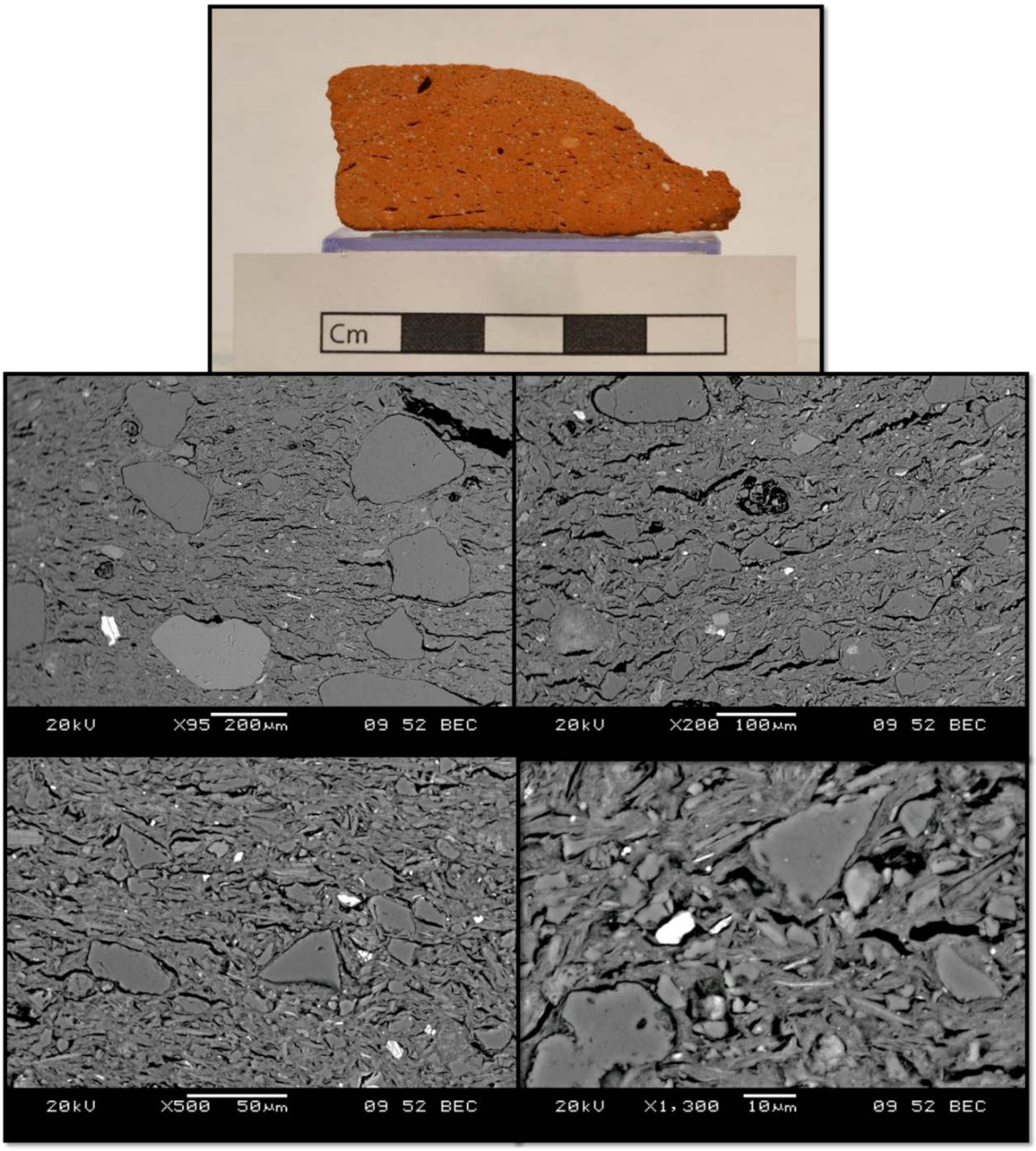


Figure C2. 24: Sample 3152.3 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3199.1

Hand Specimen Description: Dark grey core, browny outer stripe, to dark bluey black outermost. Vitrified bubbly texture. Highly fired? Rare quartz, small-medium size. Large dark lumps, some partially burnt out… vitreous material? Iron oxides?

Thin Section Description: Highly porous, with that possibly vitrified interior. Outside shows swirls of clays, smearing of top surface, with uneven inclusion of large iron rich lumps. Porosity in core dominated by small round pores (image 806). Only quite rare quartz, (809 with xpl, showing all pores except few qtz); generally medium, sub angular. 818 also good. 825 shows the high sintering, or indeed vitrification of the matrix: no visible inclusions at all.

SEM Description: no SEM

Chemistry: No chemistry.

Fabric: Fabric 5

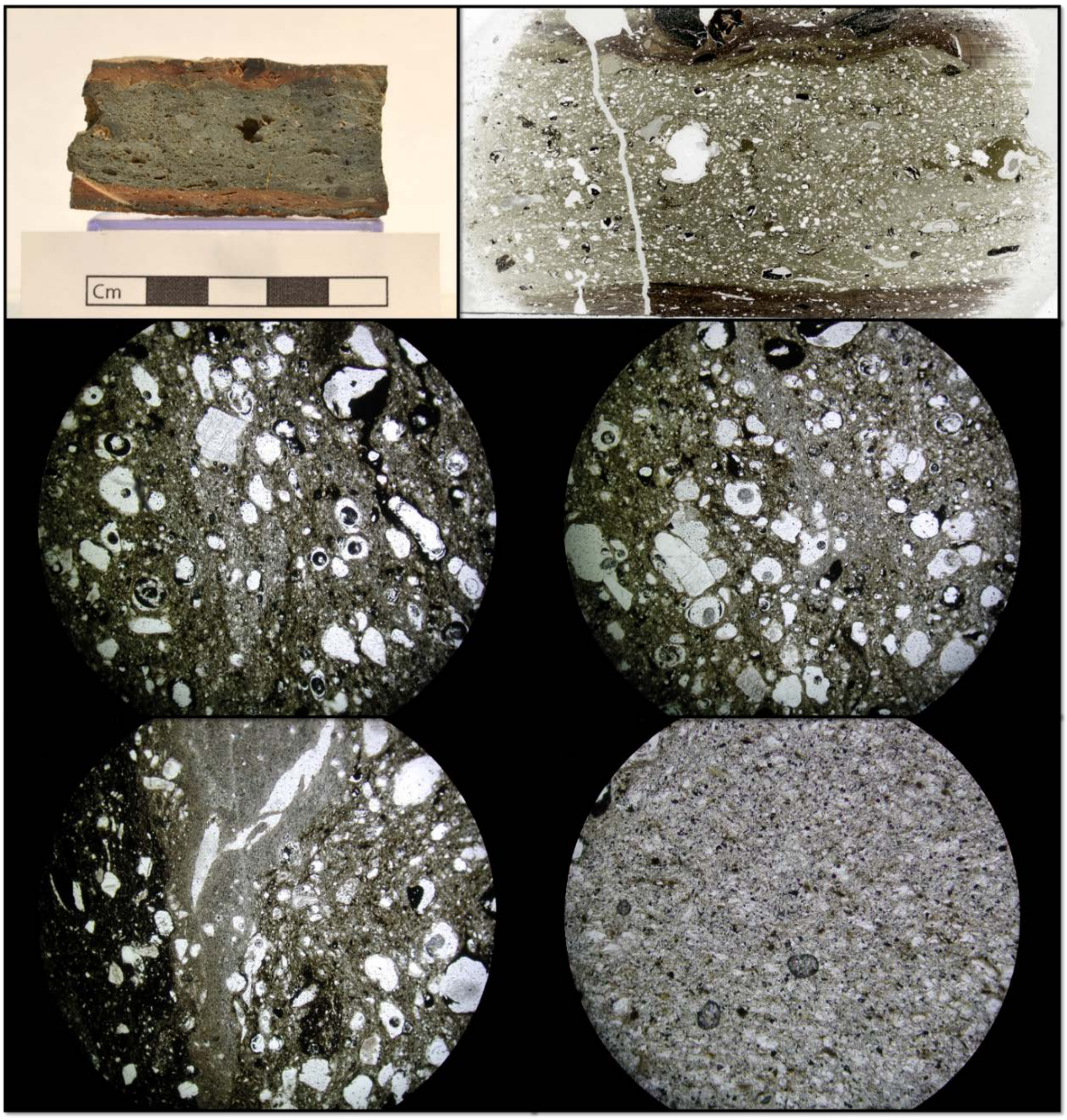


Figure C2. 25: Sample 3199.1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 and x 100 magnification.

Sample ID: 3213.1

Hand Specimen Description: A mid orange outer, and grey core; abundant large quartz inclusions, and frequent larger and smaller shrinkage pores. Brittle feel to the fabric.

Thin Section Description: N/A

SEM Description: A fabric dominated by very frequent very large sub-angular quartz, between 200 and 600 µm, with occasional potassium feldspar of same size fraction. Moderately rare medium quartz, c. 50 µm, sub-angular, with some heavy minerals in same size range, iron and titanium oxides; dominant small fraction, quartz predominantly, with occasional heavy inclusions and micas, 5 – 10 µm. Clay body appears to be quite highly fired, with tiny vitrification bubbles on the clay minerals, but small quartz not particularly melted into body, and some remaining plateyness apparent. Lots of very very small rounded pores, and also very large longitudinal shrinkage cracks and large rounded pores, possibly from removal of quartz during polishing.

Chemistry: 5th highest Al, otherwise rest middling.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3213.1	63.67	21.51	0.99	7.27	4.03	1.66	0.87

Fabric: Fabric 6

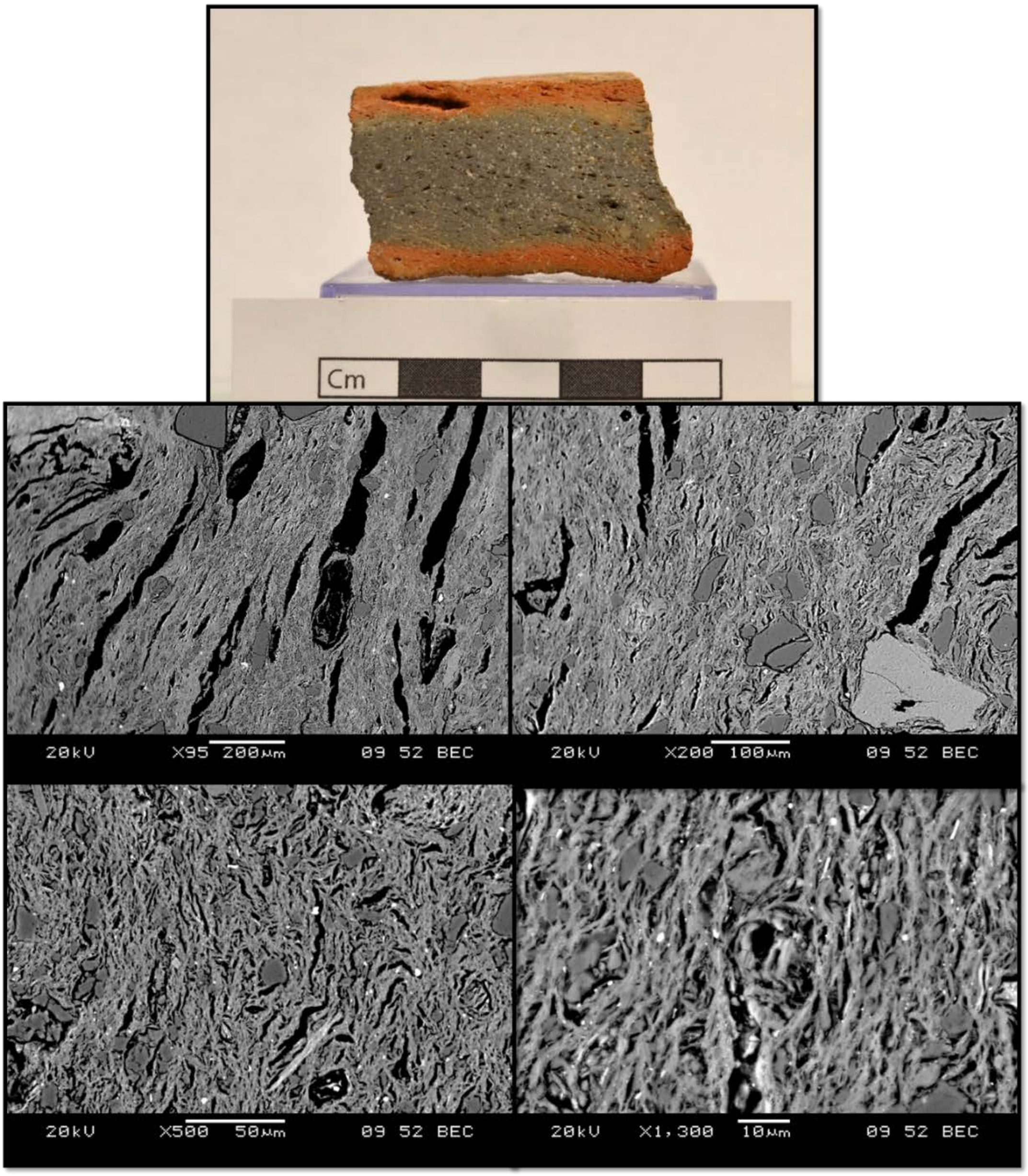


Figure C2. 26: Sample 3213.1 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3213.2

Hand Specimen Description: Very hard, solid feeling fabric, dark black outer, with a reddish brown inner layer and a dark bluish black inner core, highly porous, with small round vitrification bubbles. Reddish brown layer doesn't have many pores. Infrequent large quartz visible, a large rectangular inclusion, and occasional clay beads.

Thin Section Description: N/A

SEM Description: Clear split between the highly porous core and the mostly non-porous outer layer. Moderately abundant large quartz inclusions, 100 – 300 µm, and occasional large iron rich clay areas. Smaller quartz, 5 – 20 µm, losing crystal boundaries and melting into clay body. Clay body forms a very smooth continuous liquid surface, with, in outer, occasional small rounded pores, and in core frequent very large round pores up to 800 µm. Frequent very very small heavy inclusions, generally iron and titanium oxides, less than 1 µm.

Chemistry: quite high Si, low Ca. Quite low Fe, quite high K.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3213.2	67.71	19.15	0.45	5.79	4.21	1.68	1.00

Fabric: Fabric 5

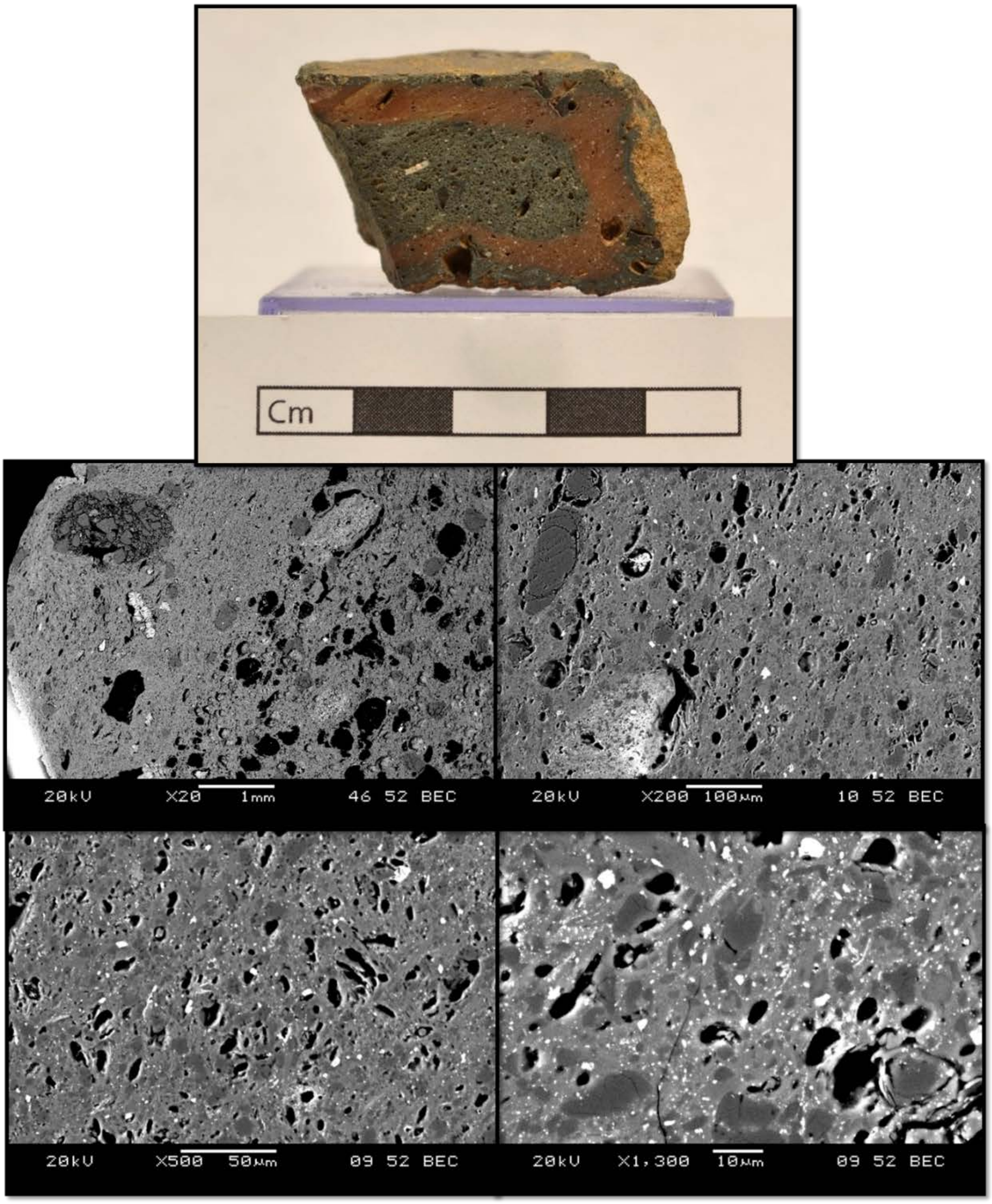


Figure C2. 27: Sample 3213.2 in hand specimen and in SEM backscatter micrographs at x 20, x 200, x 500, and x 1300 magnification.

Sample ID: 3367.1

Hand Specimen Description: A pale orangish brown, with a orangish grey core. Quite frequent large quartz visible, and occasional round clay beads. Slightly porous looking fabric, with a brittle feel.

Thin Section Description: N/A

SEM Description: A fabric characterised by very frequent very large sub rounded and sub angular quartz, up to c. 700 µm, with occasional potassium feldspar and iron rich clay beads in same size fraction. Quartz often cracked. Small potassium feldspar quite abundant, angular, up to c. 20 µm, along with similar sized quartz. Clay matrix is quite highly vitrified with little bubbles on clay minerals, joined into almost continuous surfaces. But some plateyness remaining. Some smaller quartz and feldspars starting to melt into matrix. Infrequent large rounded pores, up to about 100 µm, and occasional large longitudinal shrinkage cracks.

Chemistry: 4th highest K. Otherwise all very middling.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3367.1	64.97	20.29	0.86	7.15	4.33	1.61	0.80

Fabric: Fabric 6

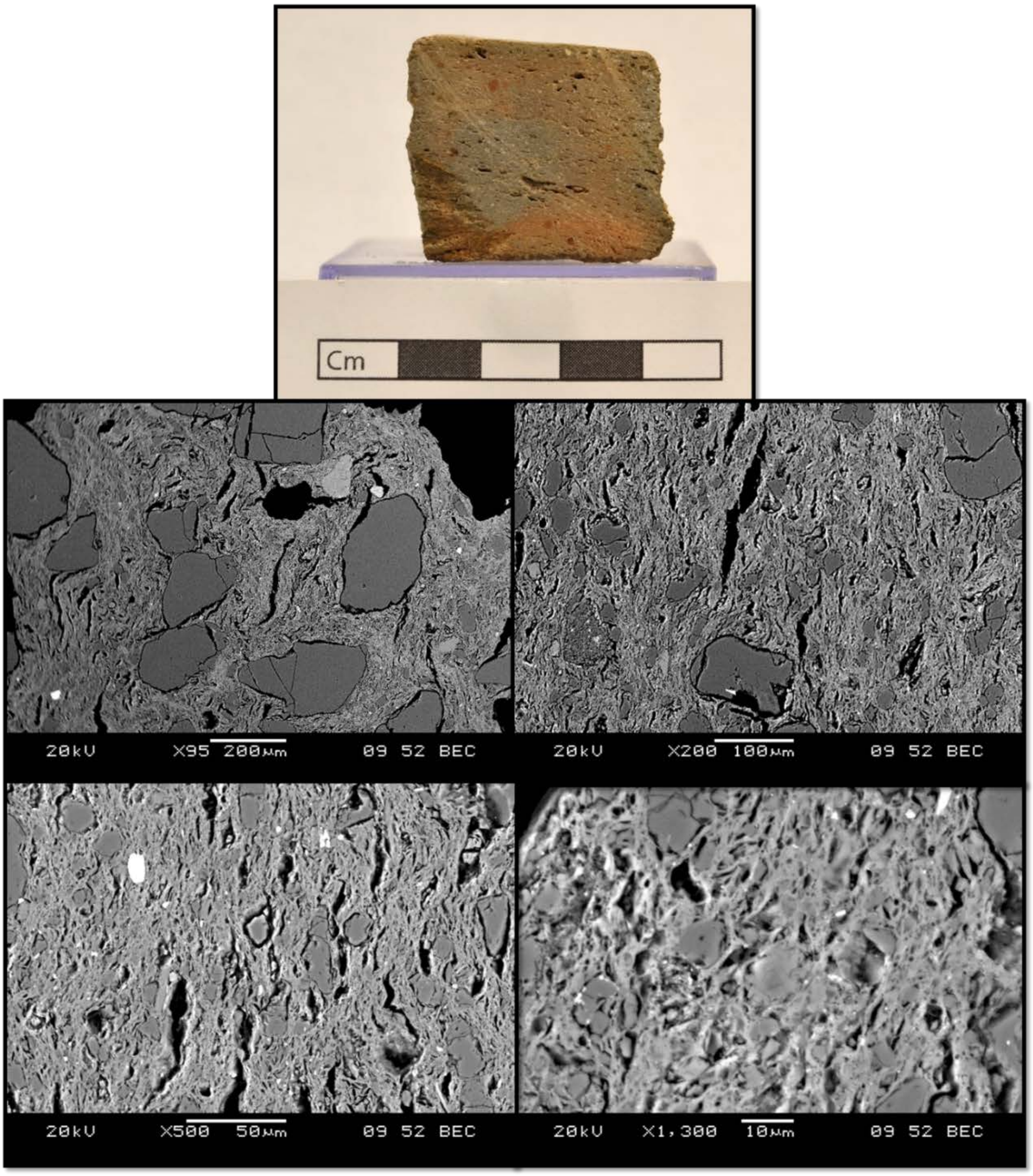


Figure C2. 28: Sample 3367.1 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3415.2

Hand Specimen Description: Varying colours of light grey to dark grey to brownish grey from outside inwards. Moderately abundant quartz, medium. Some white calcareous inclusions, occasional black and gingerish shiny inclusions. Some small rounded pores and longitudinal pores.

Thin Section Description: Relatively even, well-sorted fabric, but showing a bimodal distribution of quartz crystals, large sub-angular vs very small sub-angular. Occasional large iron oxide blobs. Some large pores, longitudinal, voids in the CBM. Plus some where qtz grains ripped out during polishing? Distribution of large (added) qtz not quite even. Fired to quite a different colour than most pieces above… Occasional rounded clay bead, from hands of tile maker? High mag shows possible occasional very small ?muscovite.

SEM Description: Moderately abundant large rounded quartz, between 100 and 600 µm, with occasional large iron rich rounded clay beads, c. 200 µm. Dominant fraction of angular small and medium quartz, potassium feldspar, and iron and titanium oxides, very busy and mixed, generally between 20 and 60 µm, with some micas. Clay matrix quite sparse, microtexture dominated by small inclusions, but shows quite high level of sintering – vitrification, without melting the smaller quartz inclusions. Some very large sub angular and longitudinal pores, but quite low porosity on the micro level.

Chemistry: Slightly low Si. Third highest K. Quite high iron. Very slightly Calcareous (c. 1%).

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
3415.2	63.05	20.34	1.16	7.85	4.54	2.02	1.03

Fabric: Indiv.

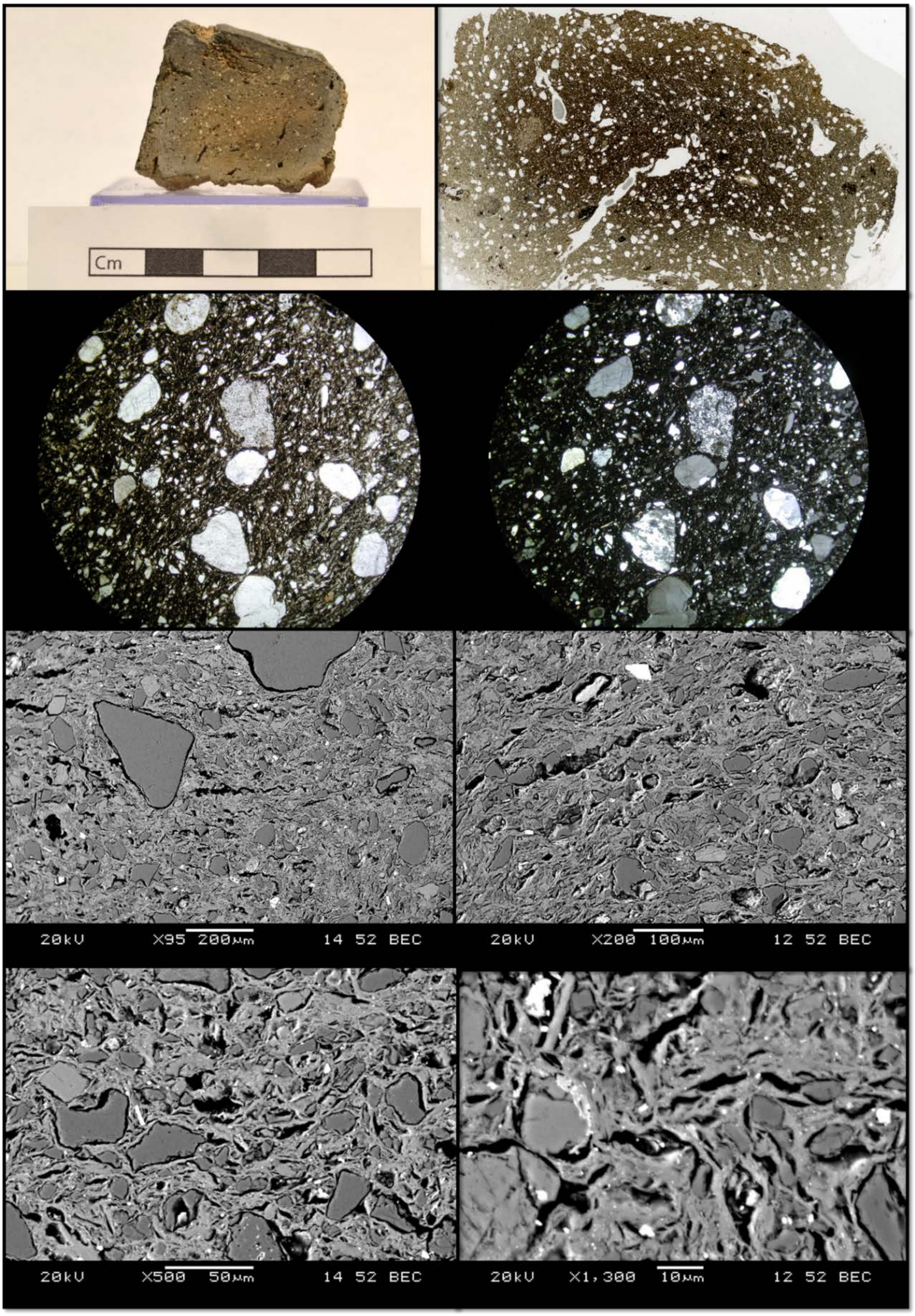


Figure C2. 29: Sample 3415.2 in hand specimen, thin section macrograph, thin section micrographs under plane and cross polarised light at x 40 magnification, and SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3416.1

Hand Specimen Description: A fabric characterised by a dark reddish orange colour and a relatively soft, friable feel. Rare large quartz inclusions are visible in hand specimen, and moderately frequent large rounded clay beads, both orange and cream in colour. Large sub rounded and sub angular pores are clear.

Thin Section Description: N/A

SEM Description: This sample has moderately abundant large, sub rounded quartz inclusions, 100 to 200 μm, and very large rounded clay beads, c. 1.5 μm across, formed of more iron rich clay than the main body. Beneath these are moderately abundant rounded and angular quartz inclusions, with occasional potassium feldspar, around 30 to 50 μm. Micas, iron, and titanium oxides are also quite common. The clay matrix is quite highly sintered, having few pores, with micas and potassium feldspars adding to the continuous phase, but with few signs of vitrification.

Chemistry: Quite high Al, 1.6% Ca, 6th highest Fe, quite high Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3416.1	63.43	20.82	1.63	8.03	3.37	1.64	1.09

Fabric: Indiv.

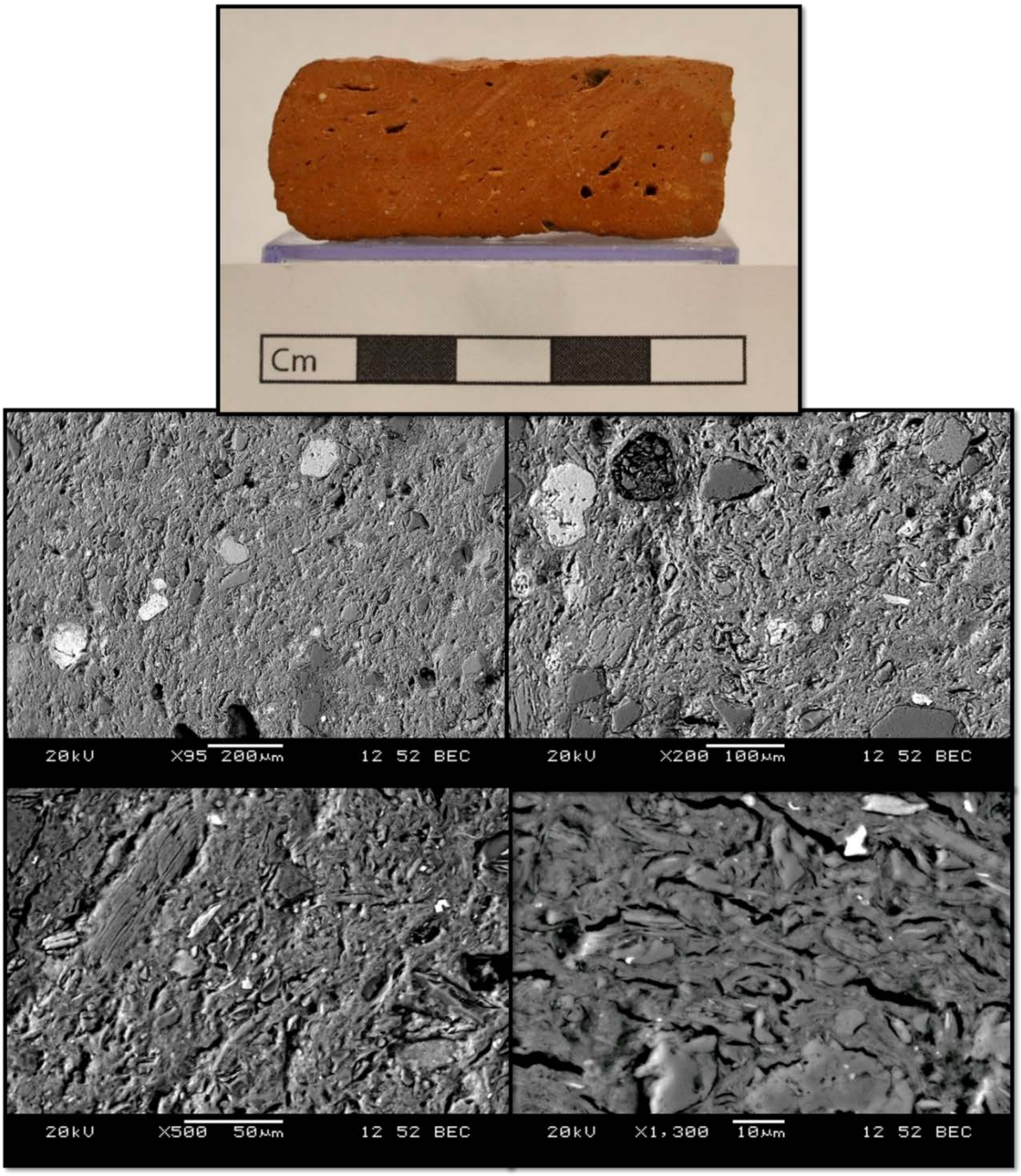


Figure C2. 30: Sample 3416.1 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3416.2

Hand Specimen Description: Dark reddish orange outer, to mid orange, to yellow, to mid bluish grey core, a moderately soft fabric, with occasional large quartz inclusions visible, and frequent rounded clay beads. Rare longitudinal pores are also seen.

Thin Section Description: N/A

SEM Description: A sample characterised by rare large quartz inclusions (angular, c. 200 µm), moderately abundant medium quartz, c. 50 µm, with iron and potassium feldspar inclusions in same fraction, and moderately abundant small, 10 – 20 µm quartz and potassium feldspar inclusions. Clay matrix is somewhat platey, linearly aligned, but with frequent shrinkage gaps between clay minerals; clay minerals are slightly vitrified, with little round bubbles.

Chemistry: 1.6% Ca. Middling Si and Al. Middling for most other things.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3416.2	65.65	20.46	1.64	6.89	3.11	1.22	1.02

Fabric: Indiv.

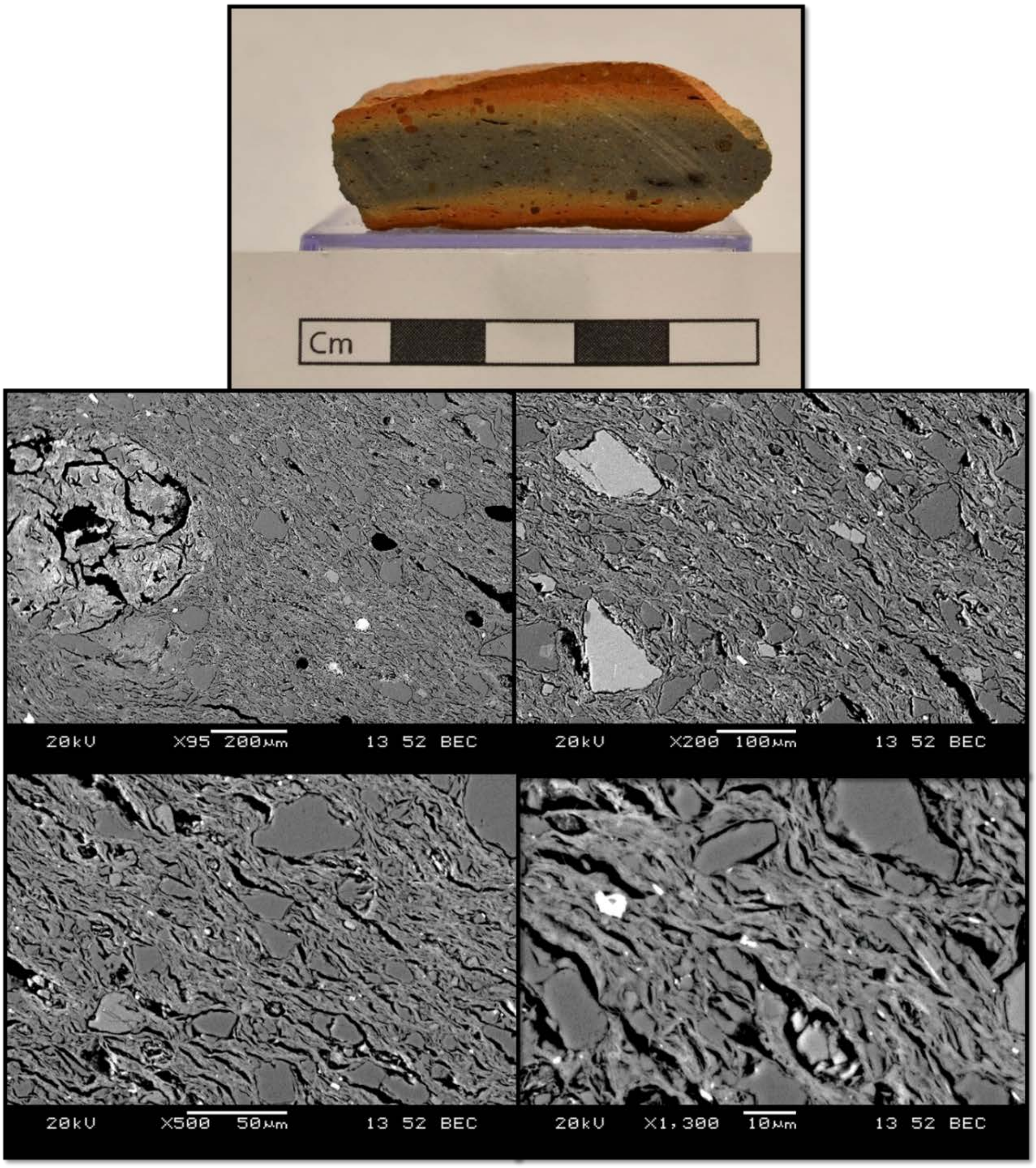


Figure C2. 31: Sample 3416.2 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3416.3

Hand Specimen Description: Reddish orange upper, thin dark grey stripe along bottom (2mm). Coarse fabric, abundant medium quartz inclusions. Rare red irony dots.

Thin Section Description: Very high density of large angular/subangular quartz; some very small pieces, but no particularly apparent bimodal split. Also moderately abundant black iron oxide inclusions, roughly same size at quartz, but rounded. Large clay bead on one edge. Longitudinal cracks aligned with east-west of piece, shrinkage from firing. Low porosity, seems to mainly be where quartz grains have been ripped out during polishing. High body colour, almost black, possibly also reflecting high iron content?

SEM Description: A fabric dominated by its quartz inclusions, which are abundant, generally rounded or sub rounded, and up to c. 1.3 mm across, although more generally between 100 and 600 µm. There is a second, moderately abundant quartz fraction, with grain sizes of between 10 and 30 µm, generally sub angular. Potassium feldspars are occasionally seen, most commonly with sizes of c. 100 – 250 µm diameter, and sub rounded shapes. These are frequently highly degraded, developing cracks and substantial porosity. Iron oxide inclusions are frequent, both in terms of occasional rounded iron rich clay beads, c. 50 – 300 µm, and frequent very small grains embedded in the clay matrix. Moderately abundant very small titanium dioxides, and rare monazite, a phosphate mineral containing rare earth metals, were also seen. The matrix is generally smooth, being highly sintered or even vitrified. The small fraction of quartz crystals and the potassium feldspar crystals are generally becoming a part of this liquid phase. With the matrix melted together the porosity is relatively high due to shrinkage of the clay component.

Chemistry: Second lowest Mg. Quite low Al. Second lowest K. Essentially non calcareous. 4th highest Ti. Second highest Fe.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3416.3	67.24	18.77	0.80	8.61	2.35	1.04	1.19

Fabric: Indiv.

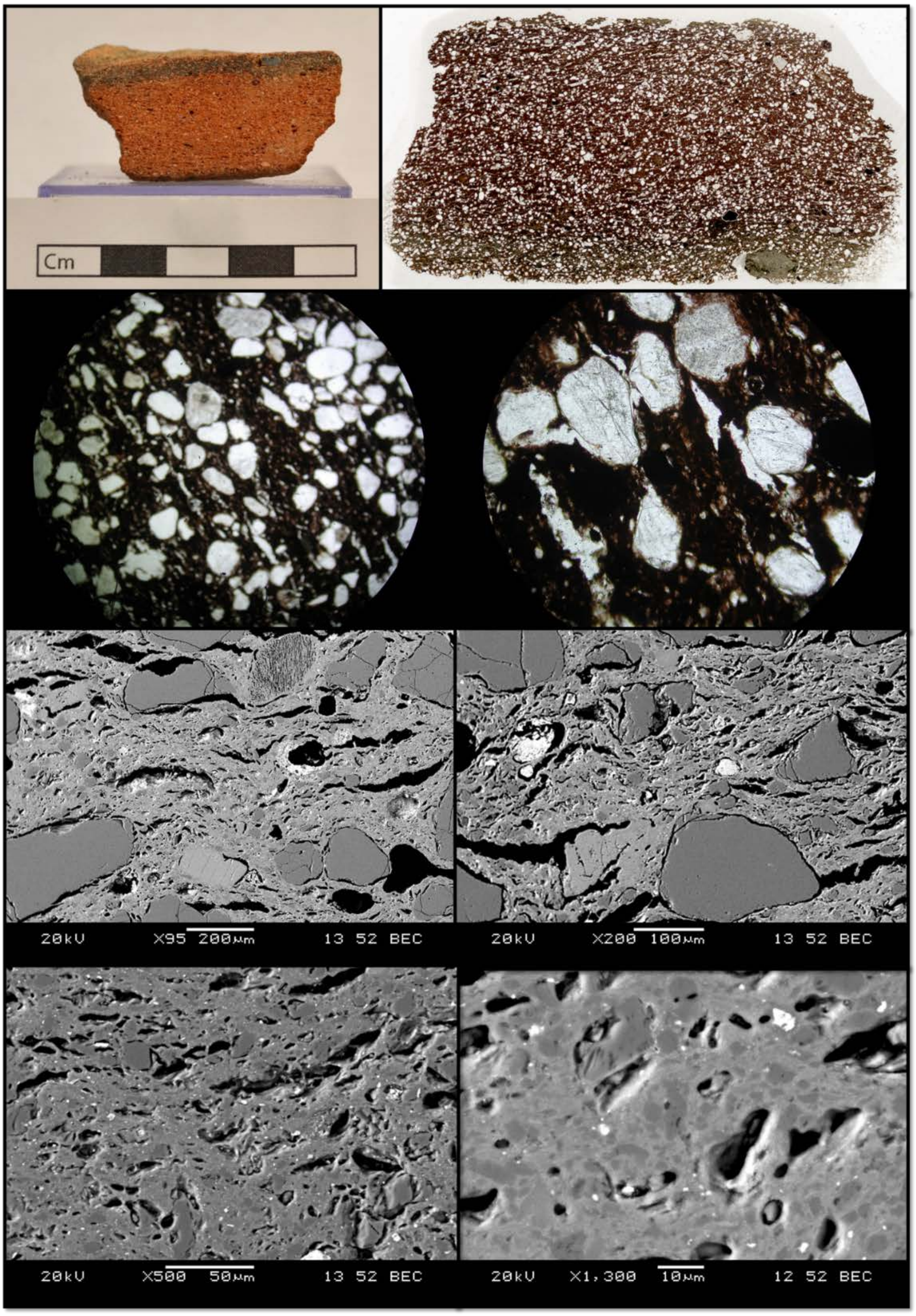


Figure C2. 32: Sample 3416.3 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 and x 100 magnification, and SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3416.4

Hand Specimen Description: A soft fabric with a mid-orange outer, to yellow, to light bluish grey core. Very few large inclusions are visible, but it has frequent large rounded pores, and one or two possible shell fragments.

Thin Section Description: N/A

SEM Description: A smooth looking fabric with few large inclusions but frequent large angular and sub rounded pores, up to c. 300 µm across, and smaller ones, rounded, c. 50 µm across. Largest quartz c.100 - 200 µm, but rare, generally angular. Dominant fraction is moderately abundant sub rounded quartz, and rare potassium feldspar. Some iron and titanium oxides and micas, plus a sodium chloride growth. Clay matrix appears highly sintered, if not vitrified – abundant very small round pores, and clay minerals closely packed into continuous surfaces.

Chemistry: 7.5% Ca – quite high. Middling for everything else.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3416.4	60.62	19.60	7.56	6.46	3.17	1.67	0.92

Fabric: Indiv.

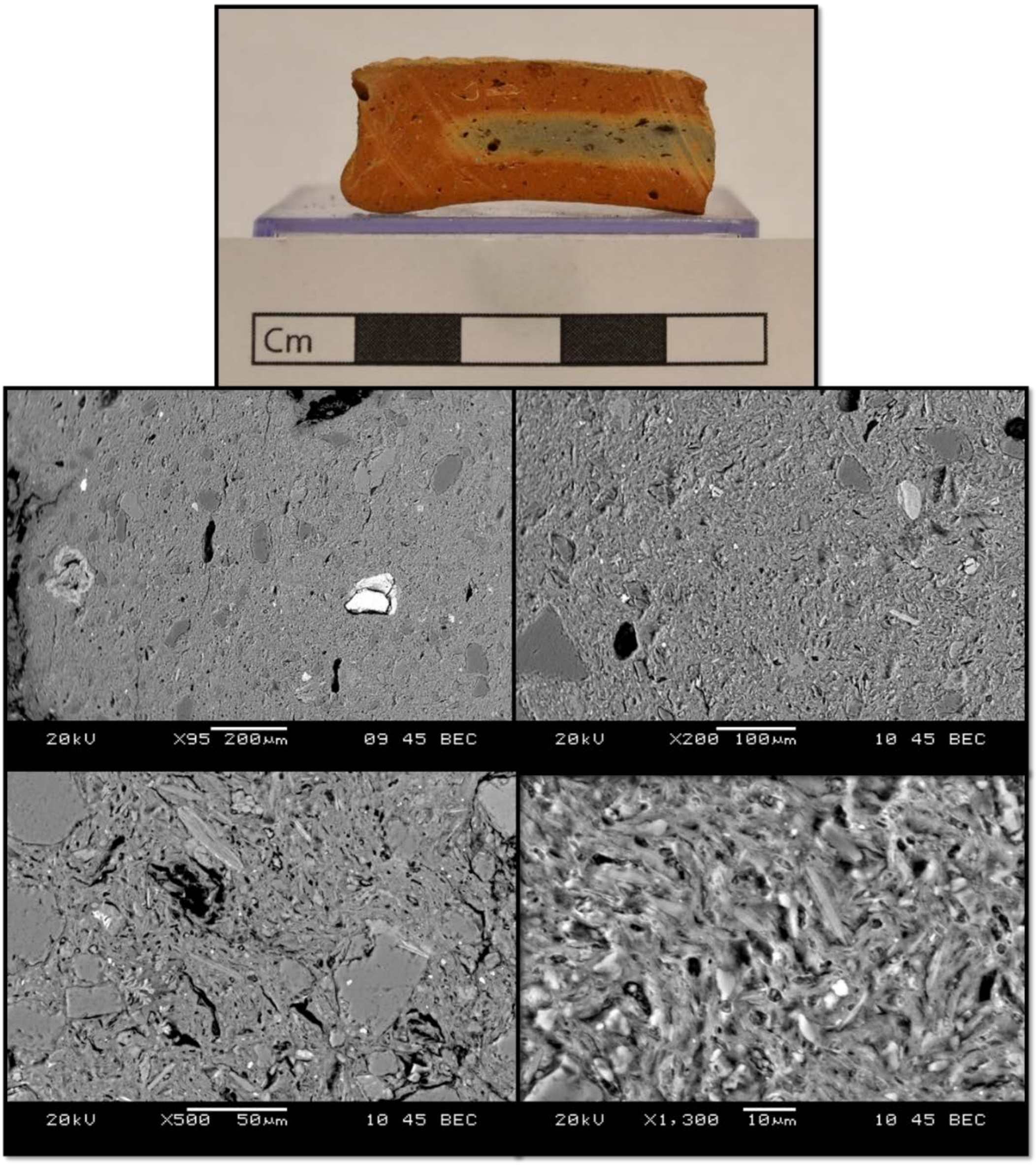


Figure C2. 33: Sample 3416.4 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3471.1

Hand Specimen Description: Brownish buff exterior, pale orange interior – efficiently and evenly fired. Rare medium and large quartz. Relatively frequent black and red shiny blobs, rounded… irony clay beads? A few fissure pores from shrinkage.

Thin Section Description: Clearly grog tempered. Grog has different distribution of quartz grains, and very different body colour. Latter has relatively sparse quartz, generally small, sub rounded. Grog has moderately abundant medium angular. Not much else to say? Grog grain size?

SEM Description: In SEM this fabric has large, angular pores and cracks; very few large inclusions, largest being c. 200 μm, and including both quartz and potassium feldspar, relatively rare, generally angular. The fabric is dominated by abundant small (10 – 30 μm) quartz, and some potassium feldspar, both generally rounded, possibly where their edges are joining the liquid phase of the fabric. The fabric is characterised by a highly vitreous appearance, clay minerals all joined into a honeycomb network, with abundant small round pores. Across the piece are several large and very large pieces of grog, generally angular, and of slightly different fabrics than the main body, having different vitrification textures and mineral sizes and proportions.

Chemistry: 4th lowest Al. 4th lowest Si. Second highest Ca.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3471.1	58.1	17.4	12.2	6.0	3.1	2.2	1.0

Fabric: Indiv.

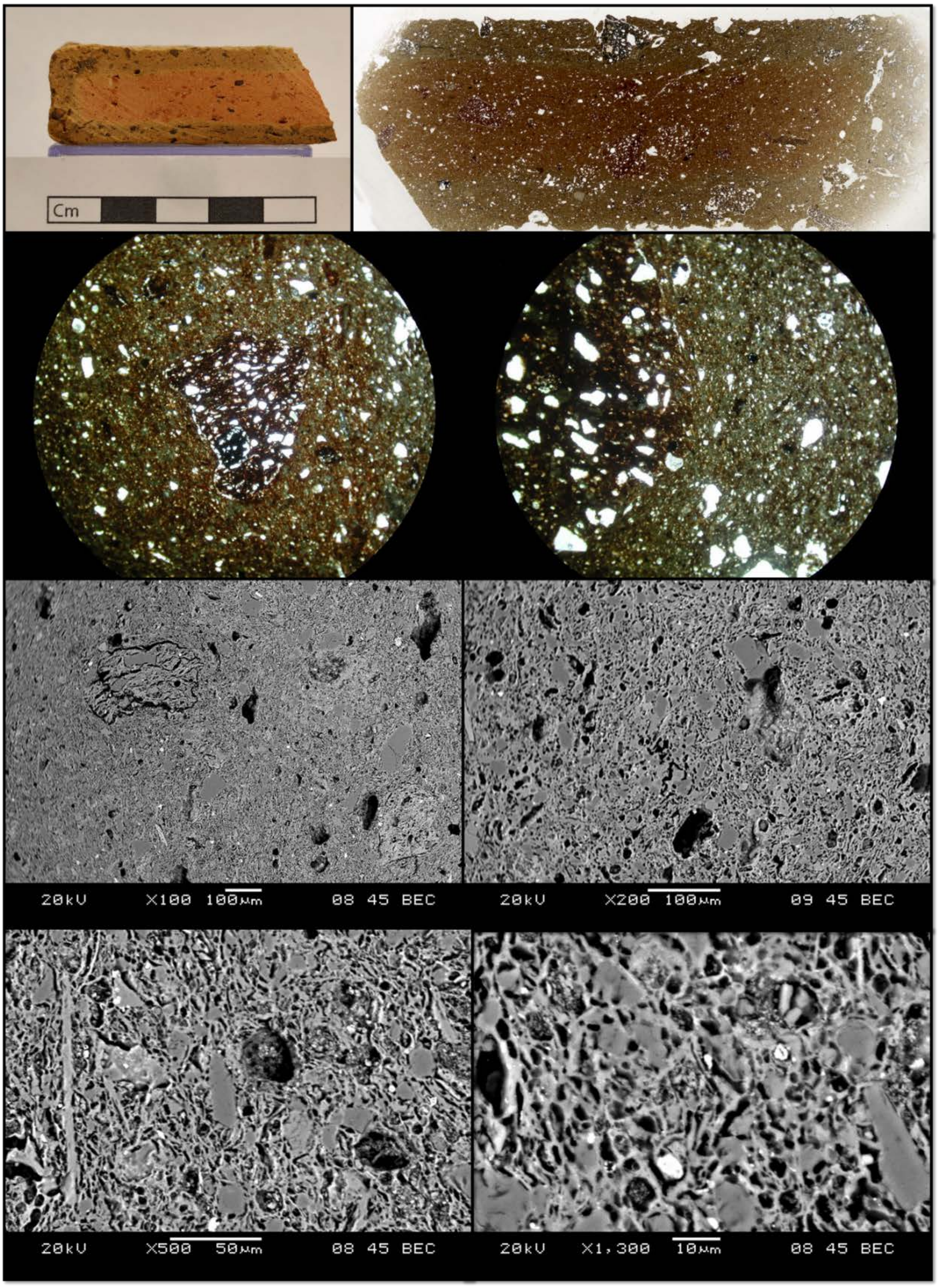


Figure C2. 34: Sample 3471.1 in hand specimen, thin section macrograph, thin section micrographs under plane polarised light at x 40 magnification, and SEM backscatter micrographs at x 100, x 200, x 500, and x 1300 magnification.

Sample ID: 3471.2

Hand Specimen Description: A mid orange, very hard, slightly brittle feeling fabric, with abundant longitudinal fractures/pores through its core, as if from shrinkage. Rare large quartz inclusions visible.

Thin Section Description: N/A

SEM Description: Fabric has rare very large rounded quartz inclusions, one or two up to c. 700 µm, but most c. 200 µm. Fabric packed with abundant medium – large angular quartz, up to c. 100 µm, with some potassium feldspar in the same size fraction, and moderately abundant framboidal iron. Also moderately abundant small rounded quartz, c. 10 µm. Microtexture is quite platey, but with clay minerals rounded and smooth, and with some signs of vitrification starting. Small longitudinal pores separate the clay minerals, whilst occasional very large angular pores characterise the macrotexture.

Chemistry: Middling for pretty much everything. Low Ca – 0.64%.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3471.2	67.24	19.05	0.64	7.19	3.28	1.78	0.81

Fabric: Fabric 3

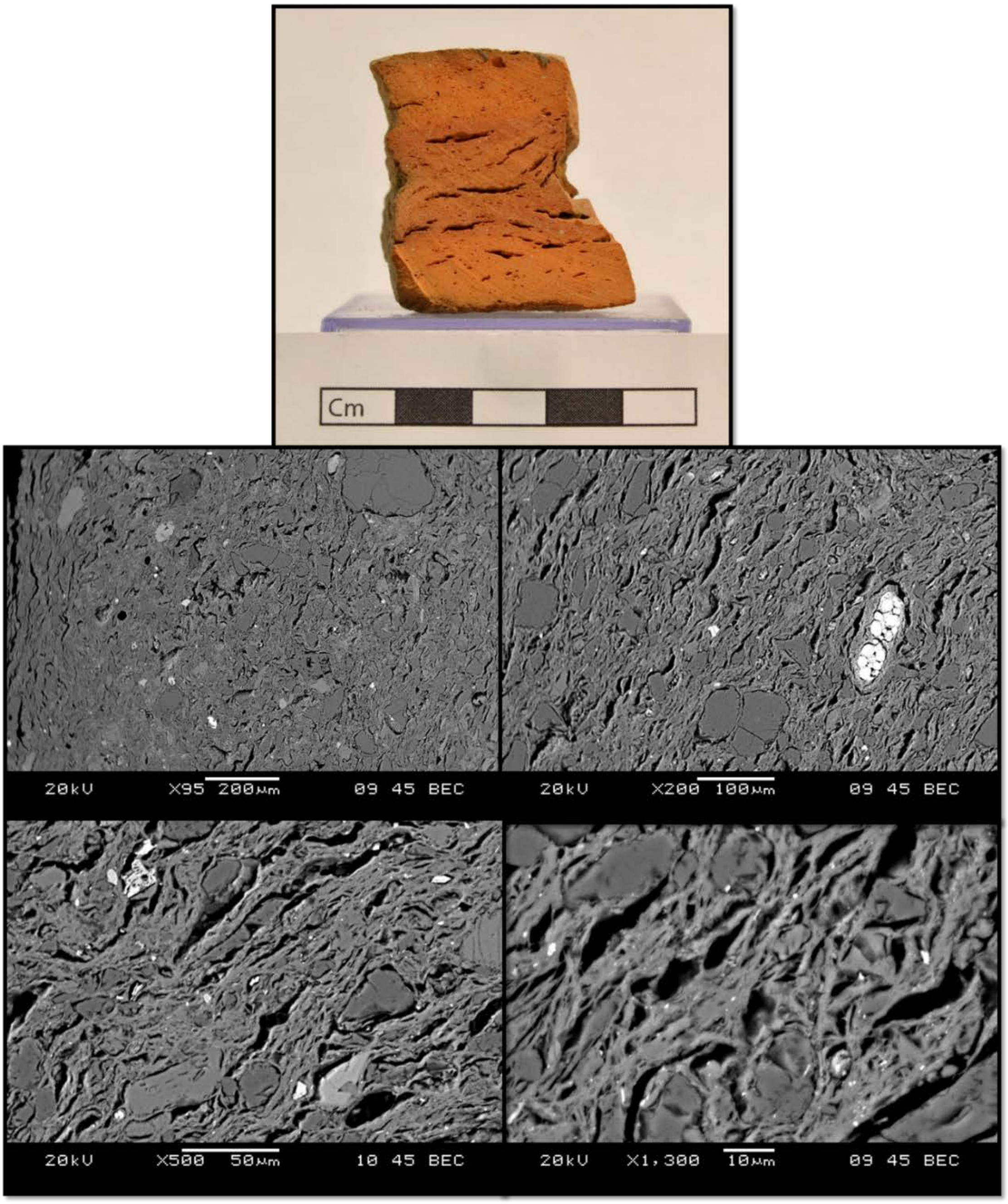


Figure C2. 35: Sample 3471.2 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3471.3

Hand Specimen Description: A pale buff – orange, fabric, quite soft and powdery to the touch. Rare large quartz visible, and very rare large pale round clay beads. One large white longitudinal mineral inclusion, shell fragment?

Thin Section Description: N/A

SEM Description: Occasional very large rounded quartz, and some potassium feldspar, 200 - 400 µm, occasionally cracked. Few medium inclusions, generally iron rich clay beads or framboids. Dominant small inclusions, moderately abundant quartz and potassium feldspar, 5 – 20 µm, beginning to join liquid phase with clay matrix. Clay matrix appears quite highly vitrified, with frequent small round pores with black cores – burnt out calcium carbonate? Ooliths?

Chemistry: Second lowest Si. 6th lowest Al. Second highest Ca, 16%. Middling for rest.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3471.3	54.52	17.46	15.97	6.08	3.23	1.86	0.88

Fabric: Indiv.

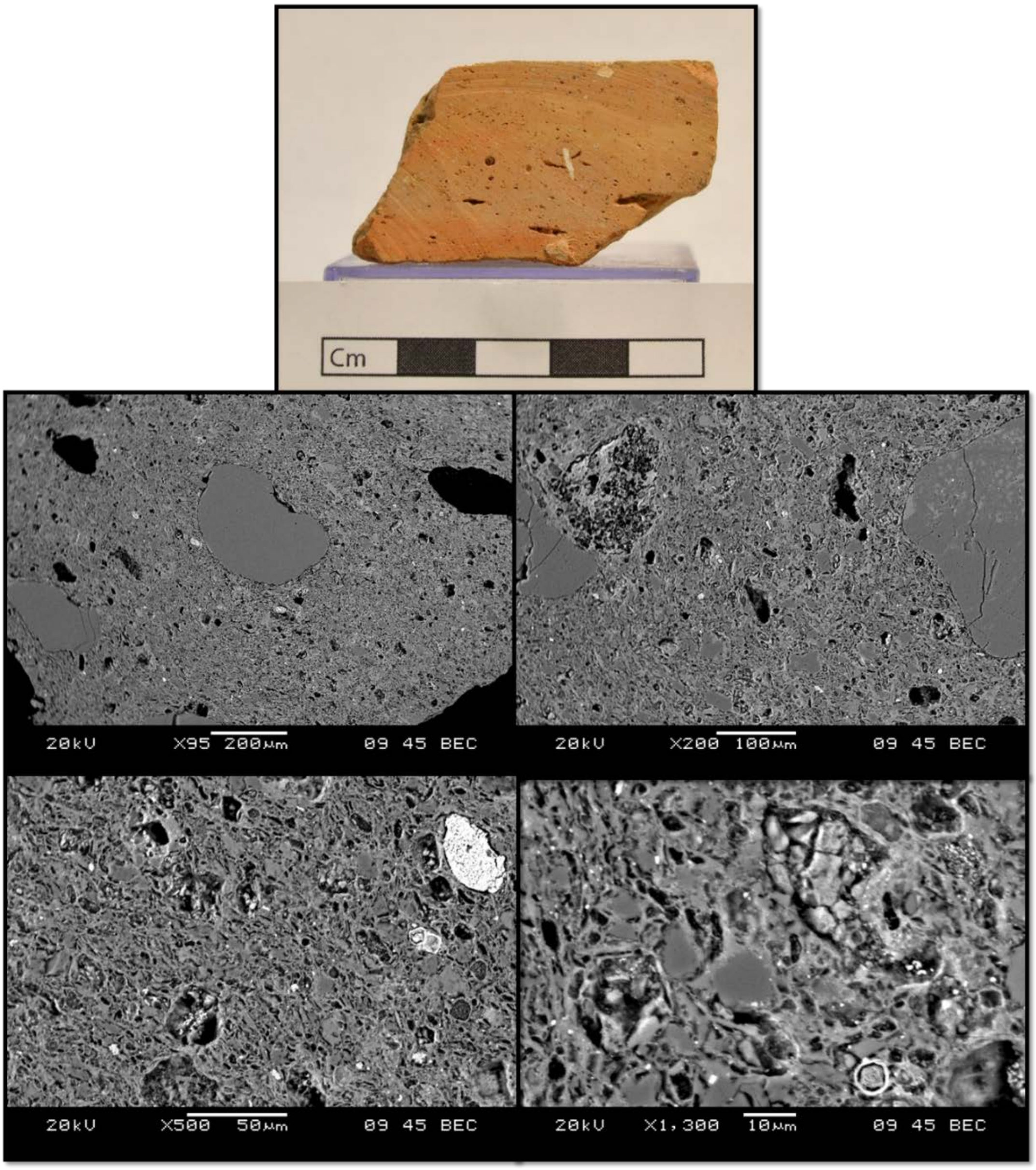


Figure C2. 36: Sample 3471.3 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3471.5

Hand Specimen Description: A dark and lighter bluish grey fabric, quite hard, with few large inclusions visible. Large longitudinal shrinkage cracks in core, and moderately abundant medium rounded pores.

Thin Section Description: N/A

SEM Description: Very few large inclusions visible, generally just the occasional iron oxide bead, some framboidal, 100 – 200 µm. Dominant mineral inclusions are c. 50 µm sub angular quartz and potassium feldspar, iron inclusions continuing to be common, and occasional micas. Microtexture is highly closed, continuous sintering or vitrification texture, with very few pores.

Chemistry: Middling (low) Si and middling Al. 1.3%Ca. Highish Fe and K, highest Mg, second highest Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3471.5	61.79	20.17	1.29	7.61	4.30	3.56	1.28

Fabric: Fabric 3

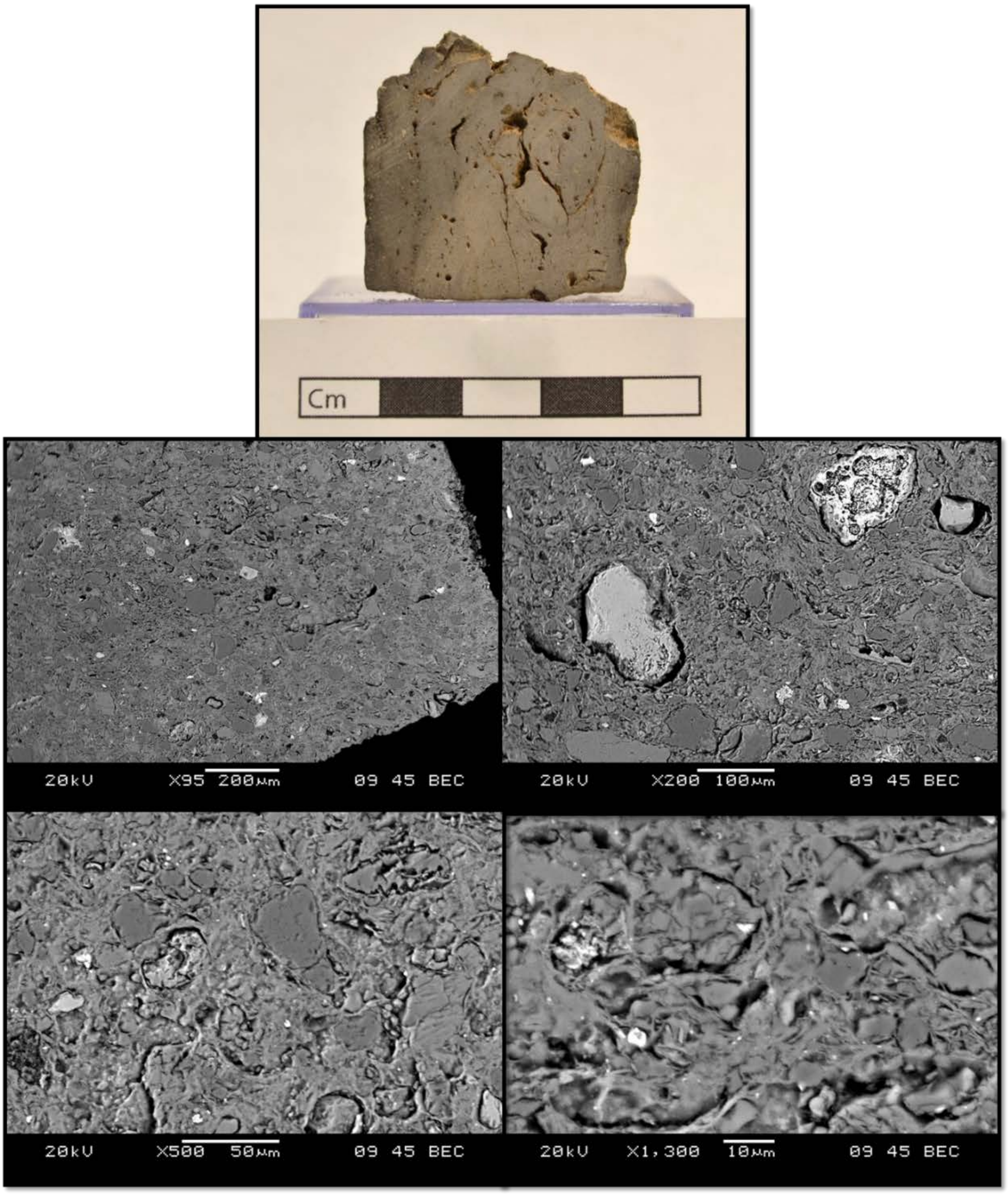


Figure C2. 37: Sample 3471.5 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3477.1

Hand Specimen Description: A slightly soft, orangey red fabric, with rare large quartz visible, but larger, possible shell fragments? Also large pores and cracks.

Thin Section Description: N/A

SEM Description: In SEM, a very disordered appearing fabric. Some very large rounded quartz, up to c. 500 µm, with some large angular potassium feldspars and iron rich clay areas. The medium and small size fraction is very mixed, including angular and sub rounded quartz, potassium feldspars, micas, calcite, bone fragments, iron rich clay beads, framboidal iron oxides, and titanium oxides. Clay body is platey, with clay minerals and micas clearly still separate.

Chemistry: Middling Si and Al, 4% Ca. 4th lowest Fe.

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
3477.1	65.70	19.35	3.97	5.50	3.16	1.55	0.76

Fabric: Indiv.

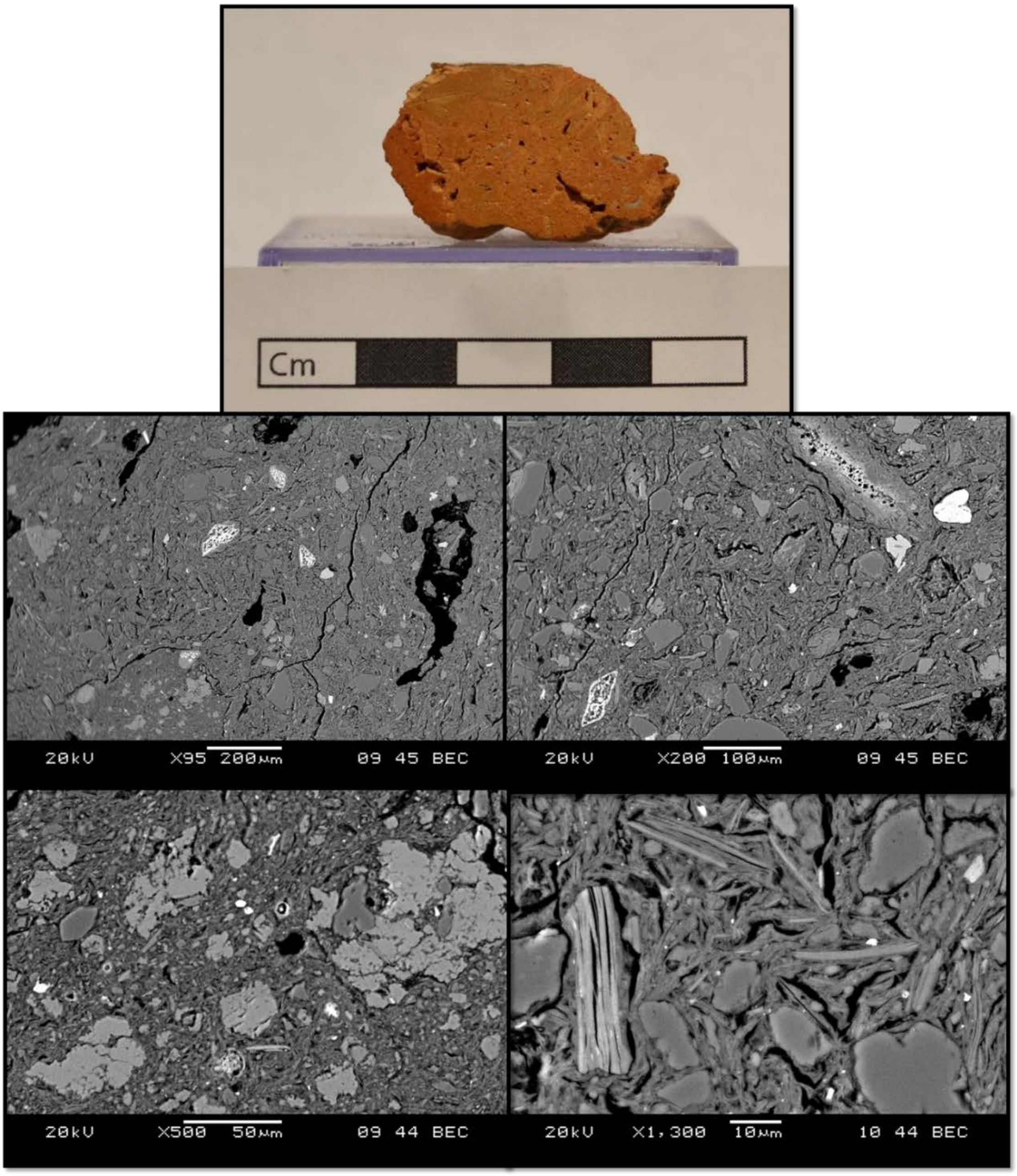


Figure C2. 38: Sample 3477.1 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3477.2

Hand Specimen Description: A grainy feeling, but quite soft light browny orange fabric. Individual large inclusions cannot be seen in hand specimen because of the texture, but from the feel is it clear that they are there.

Thin Section Description: N/A

SEM Description: A very sandy fabric, dominated by well-sorted very large rounded quartz crystals, sub angular, between 200 and 400 µm. Smaller fragments of angular quartz lie in between the large ones, often appearing broken from larger pieces, and there are relatively large iron and titanium oxides. The clay matrix appears very smooth and non porous, closely sintered together, but with longitudinal cracks around the large inclusions.

Chemistry: 3rd highest Si, 2nd highest Al, middling Ca. Lowest Fe (by quite some way – 1.7 to 5% next), Lowest K (0.2 to 2.3% next), lowest Mg (0.33 – 1% next), highest Ti (2 – 1.28% next).

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3477.2	69.79	23.34	2.56	1.70	0.23	0.33	2.06

Fabric: Indiv.

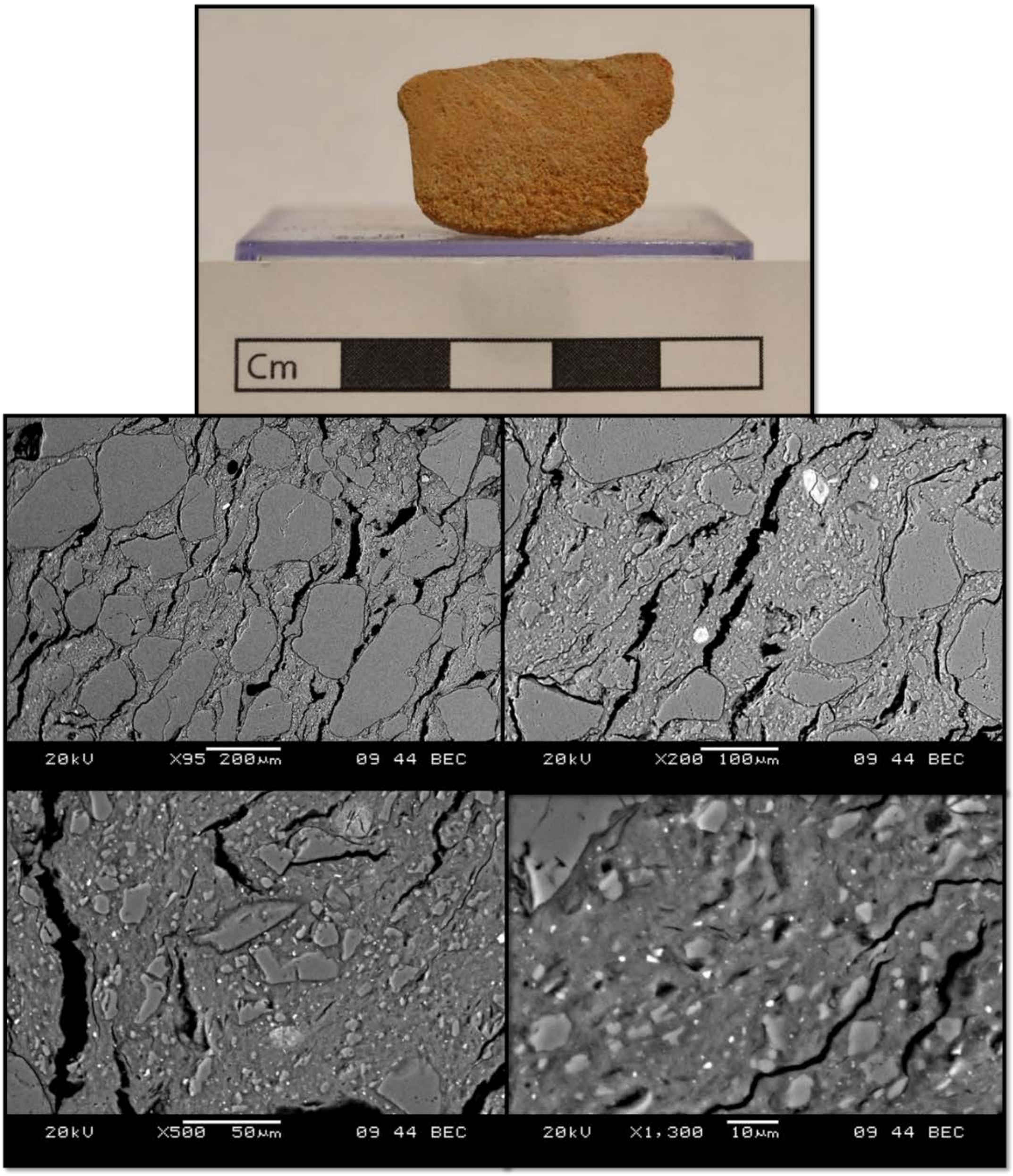


Figure C2. 39: Sample 3477.2 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3499.1

Hand Specimen Description: Mid orange outer, dark blue grey inside, then reddish brown core. Oddly fired… Large swirls of pale clay visible without magnification. Rare medium quartz, but other than this and clay blobs, quite empty fabric. Rare small longitudinal pores.

Thin Section Description: Clear banding, very neat, reflecting relative homogeneity of clay, well mixed. Very large pale clay blobs in core, rounded, suggestive of clay beads. Also very large iron rich inclusions, some rounded, some very angular, and large and medium rounded as well – v large angular = fragments of crushed rock/ceramic? Higher large quartz sand concentration on one face, suggestive of sanding for mould release. Otherwise some sparse large quartz throughout, sub rounded. And very small, silt sizes, evenly spread throughout. Some large longitudinal pores.

SEM Description: no SEM

Chemistry: no chemistry

Fabric: Indiv.

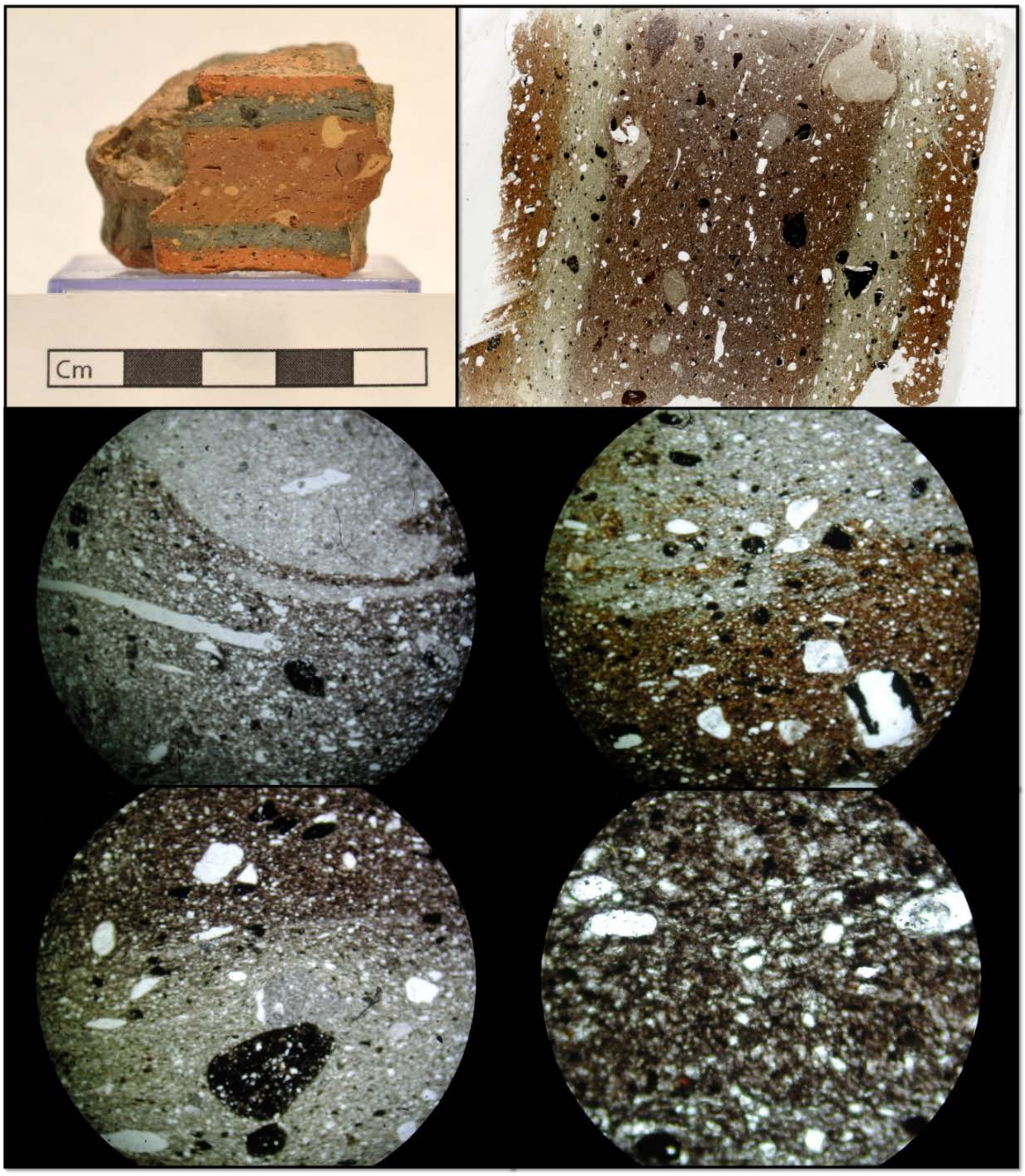


Figure C2. 40: Sample 3499.1 in hand specimen, thin section macrograph, and thin section micrographs under plane polarised light at x 40 and x 100 magnification.

Sample ID: 3658.1

Hand Specimen Description: Light-mid orange throughout, although slightly paler on outside. Multiple rounded pores, medium size. Rare small quartz. Large creamy lump, calcareous? Some medium sized red and black iron oxide beads.

Thin Section Description: Relatively few inclusions, similar to Fabric B? Rare strings of medium-large sun angular and sub rounded quartz crystals, rare large clay beads, and rare medium-large subrounded iron oxide beads. Some large pores. Moderately abundant very small, silt size, quartz.

SEM Description: Very rare large quartz, rounded, 200 – 300 μm, with very rare large potassium feldspar and iron rich clay inclusions, similar size. Dominant inclusion fraction is in the range of 30 – 50 μm, with angular quartz, potassium feldspar, and micas, in a very mixed, busy looking fabric. Also iron oxides and titanium oxides. Microtexture is quite platey, with individual clay minerals starting to look vitrified with very small round pores, but high inclusion to clay ration, and few signs of even smallest inclusions joining the liquid phase.

Chemistry: 5th highest Na and Mg. Essentially non calcareous. Otherwise middling for rest.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3658.1	64.75	19.20	1.28	6.74	4.00	3.09	0.94

Fabric: Fabric 3

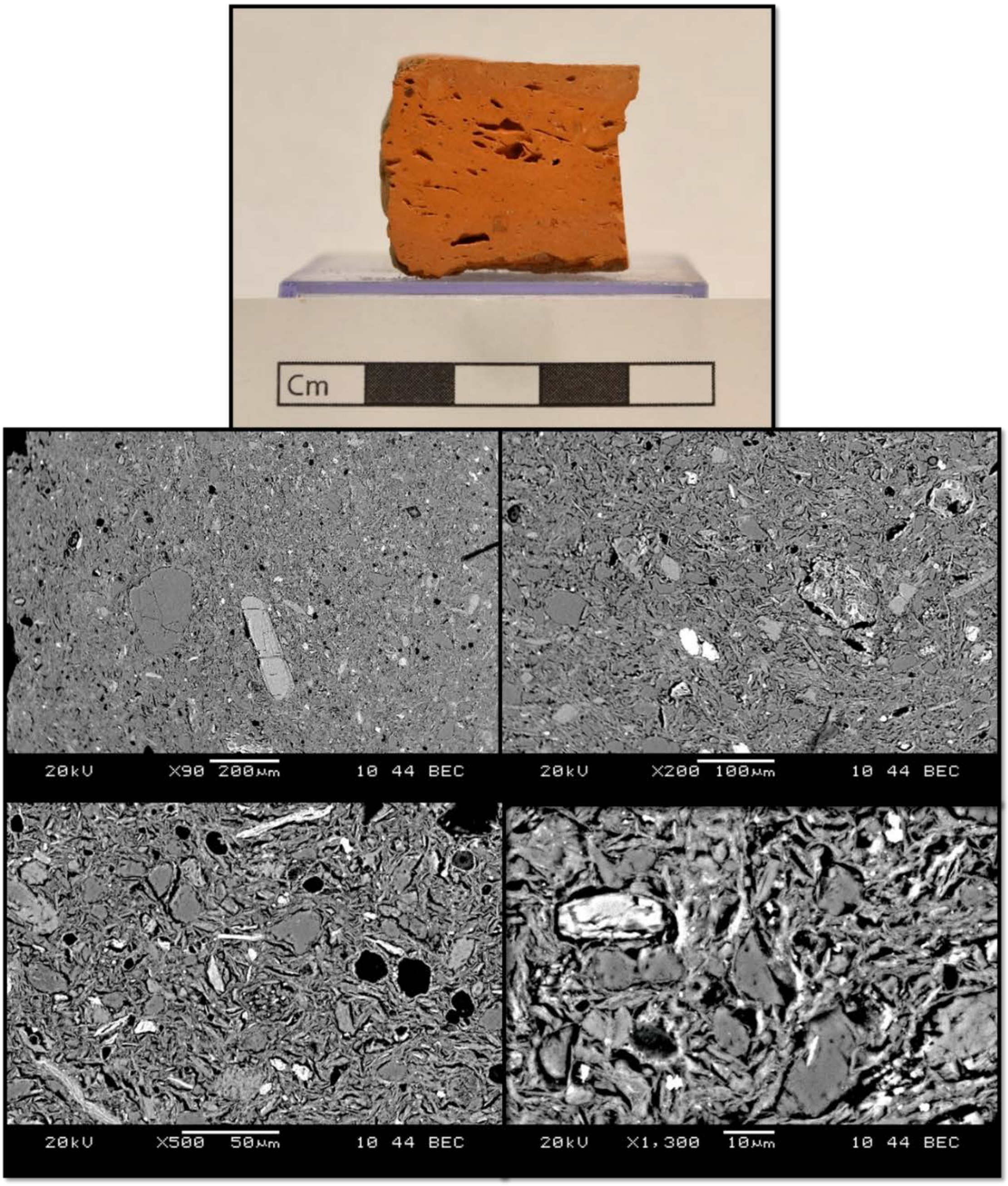


Figure C2. 41: Sample 3658.1 in hand specimen and in SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: 3658.2

Hand Specimen Description: A dark reddish orange fabric with abundant smaller and large rounded clay beads, in both a darker red colour and a cream colour. Some large quartz crystals are visible as well. The sampled piece also has abundant very large pores, both a shrinkage crack through the core of the piece, and a large rounded void which appears as if a piece of gravel was present here at the time of firing. It has a reasonably hard feel.

Thin Section Description: N/A

SEM Description: A fabric characterised by moderately abundant very large rounded quartz sand, 200 – 400 μm, with large rounded iron-rich clay beads of the same size, and very rare potassium feldspar. Occasional large rounded quartz of c. 100 μm is also present, with the dominant inclusion fraction being 10 – 30 μm, sub rounded quartz, with rare potassium feldspar and iron and titanium oxides. The clay body is slightly platey, with individual clay minerals still visible, although appear to be in the early stages of vitrification, with occasional very small pores, and connecting together.

Chemistry: Middling Si and Al; 0.5% Ca. Quite low Fe. 3rd highest Ti.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3658.2	67.51	19.89	0.51	5.60	3.86	1.37	1.26

Fabric: Fabric 4

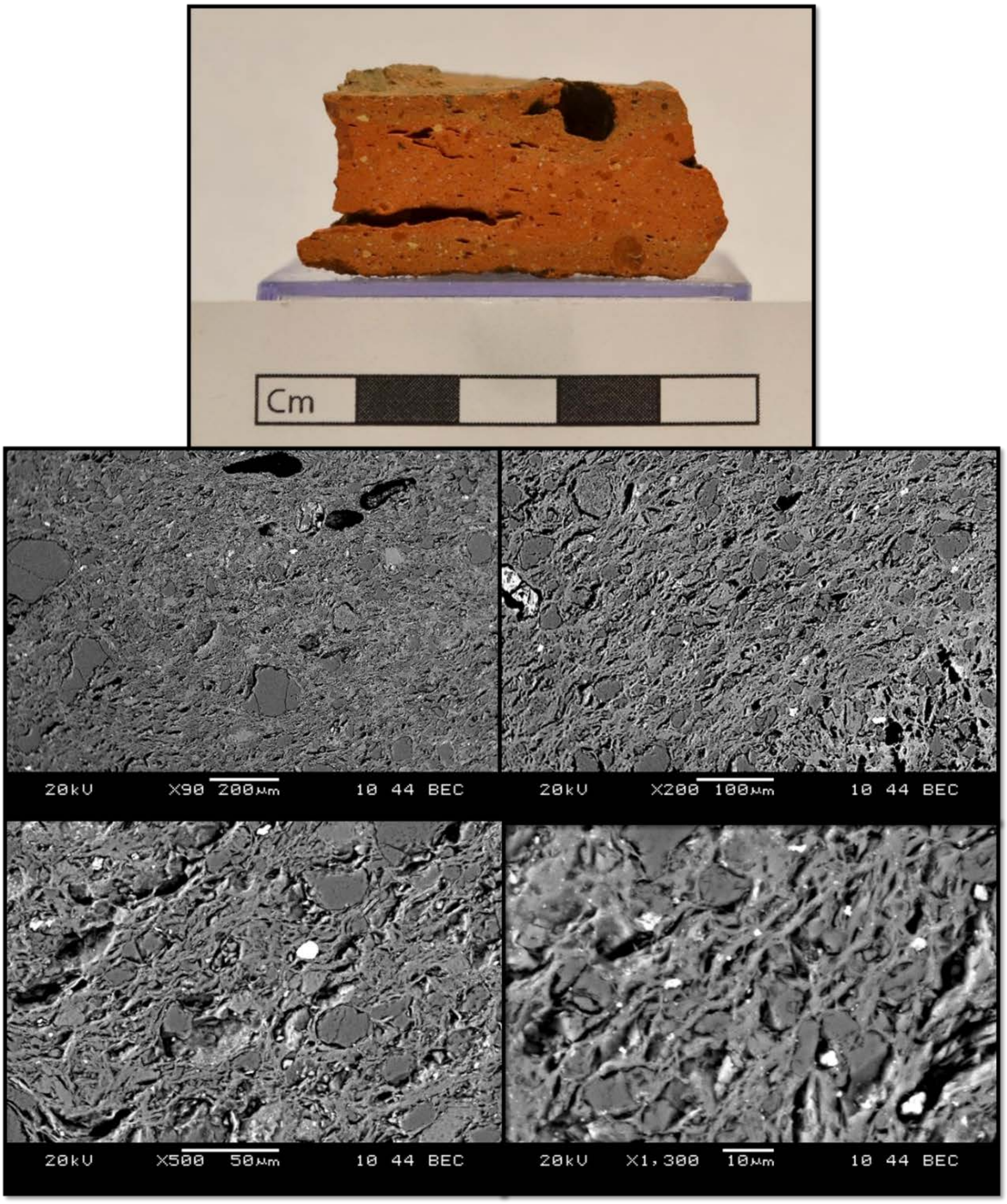


Figure C2. 42: Sample 3658.2 in hand specimen and in SEM backscatter micrographs at x 90, x 200, x 500, and x 1300 magnification.

Sample ID: 3658.3

Hand Specimen Description: A dark reddish orange moderately hard fabric, with frequent round pores, occasional dark red round clay beads, and very rare large quartz visible.

Thin Section Description: N/A

SEM Description: Characterised by having very few large quartz inclusions, sub rounded and sub angular, c. 100 – 200 µm. The dominant inclusions are in the size range of 40 – 70 µm, made up of both quartz, generally quite angular, and relatively common potassium feldspar. Occasional framboidal iron oxide beads are also present, and rare micas. Clay microtexture is slightly platey, with few inclusions joining the liquid phase, and even some clay minerals keeping their integrity.

Chemistry: 6th highest Si, 4th lowest Al, c. 1% Ca, middle for trace.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3658.3	68.31	17.15	1.13	6.66	3.32	2.50	0.93

Fabric: Fabric 3

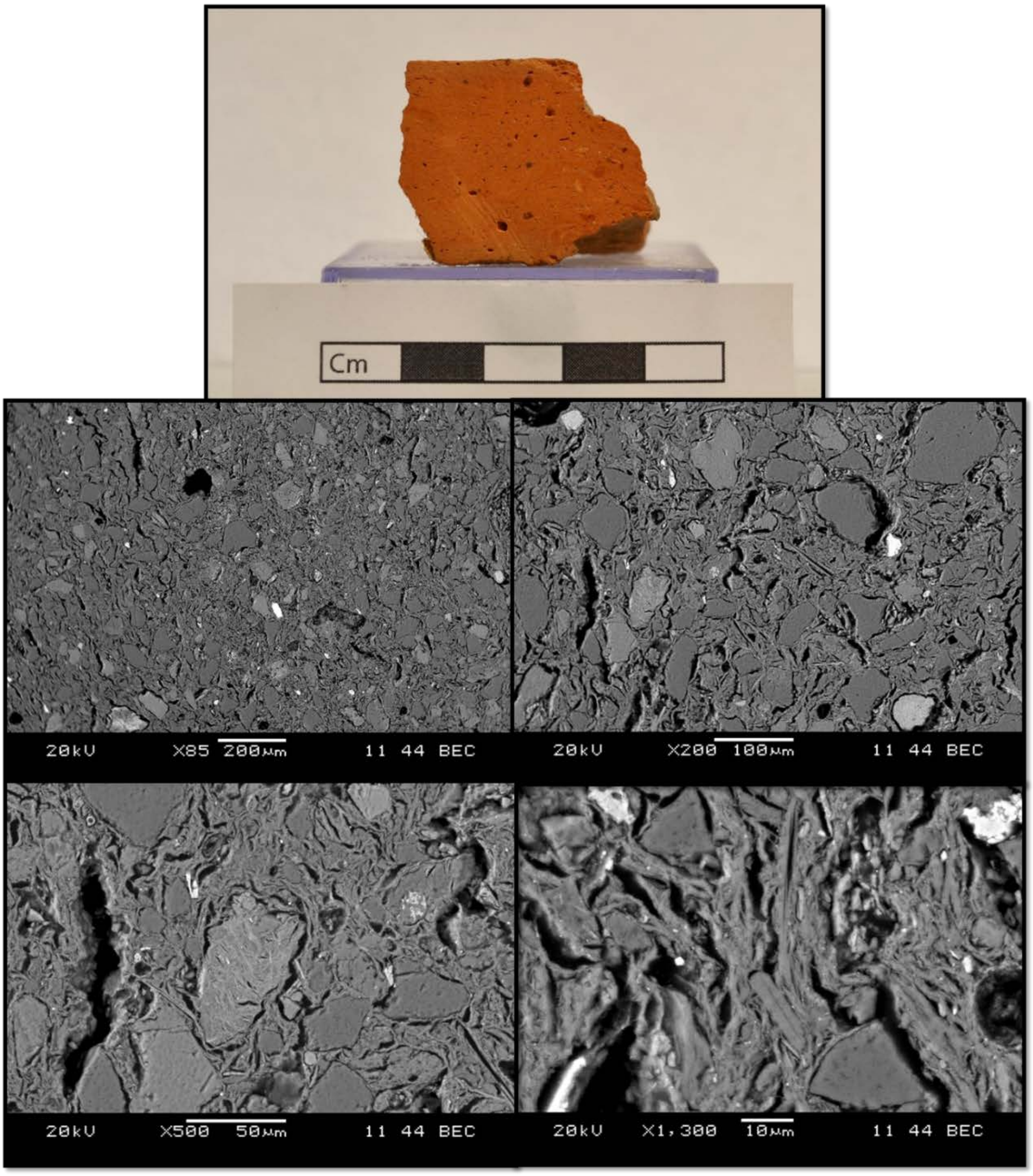


Figure C2. 43: Sample 3658.3 in hand specimen and in SEM backscatter micrographs at x 85, x 200, x 500, and x 1300 magnification.

Sample ID: 3658.4

Hand Specimen Description: A bright reddish orange fabric, with very few visible inclusions, but somewhat frequent large sub angular pores. The fabric has a very hard feel.

Thin Section Description: N/A

SEM Description: Fairly typical of fabric 3 – very few large rounded quartz inclusions, with occasional large iron rich clay beads and iron oxide framboids. Dominant mineral assemblage consists of medium and small quartz, potassium feldspar, and micas, generally in the 30 – 50 μm size range, sub angular and sub rounded. There are moderately frequent small round pores with dark centres, c. 5 μm across. Clay minerals are quite highly sintered, with the smallest micas, potassium feldspars, and some quartz joining the liquid phase.

Chemistry: Middling everything, second highest Mg.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3658.4	63.14	19.89	1.67	7.14	3.92	3.33	0.91

Fabric: Fabric 3

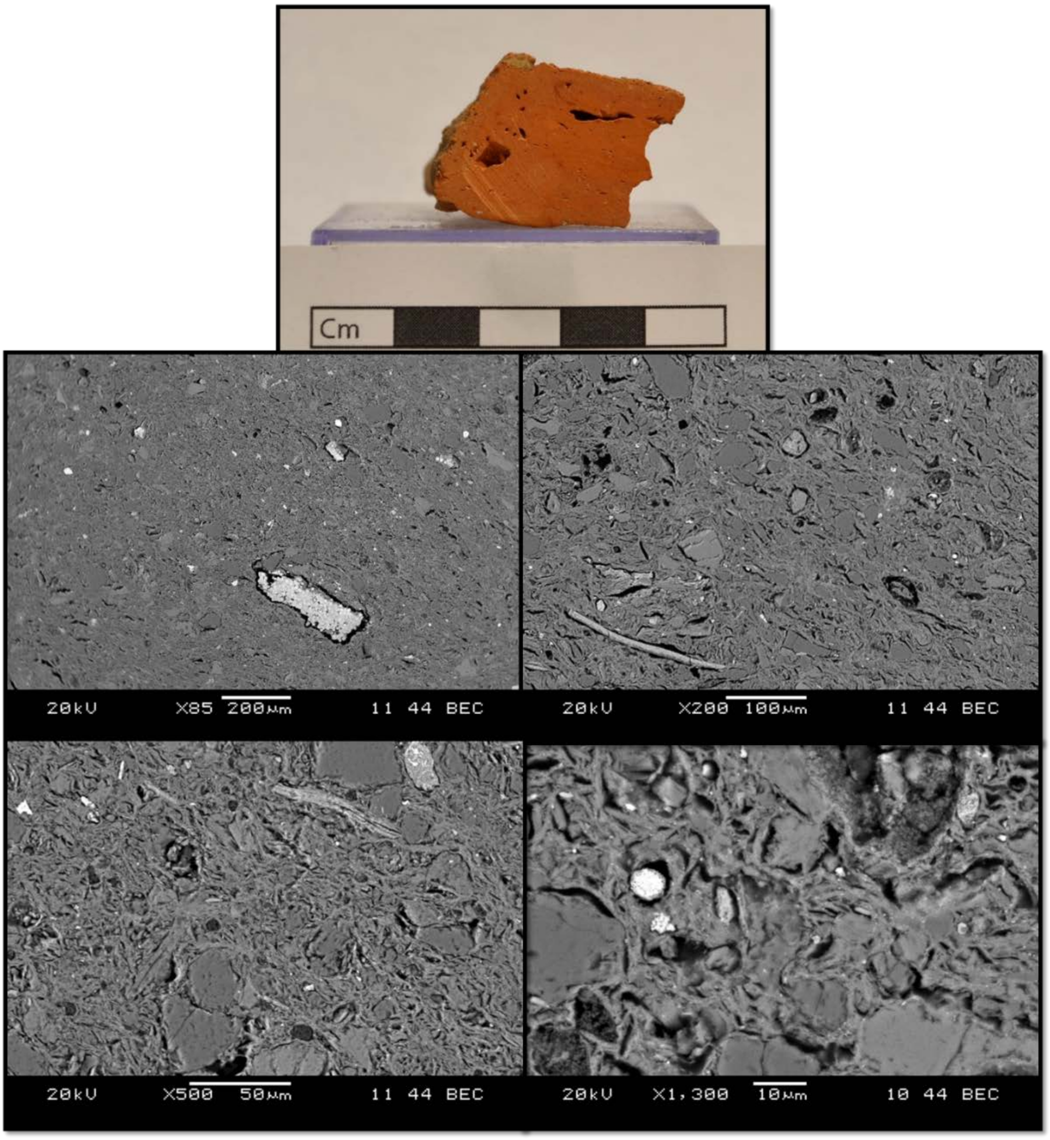


Figure C2. 44: Sample 3658.4 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Sample ID: 3671.1

Hand Specimen Description: A pale yellowish orange to dark slightly yellowish orange, quite hard fabric (showing calcareous clay colours). Frequent large quartz crystals can be seen, and occasional smaller clay beads. Some large round porosity is also visible.

Thin Section Description: N/A

SEM Description: Fabric characterised by very large very angular quartz, between 300 and 600 µm, with quite frequent potassium feldspar in the same size range, as well as large iron rich beads, sometimes framboidal. Some perthite is also apparent. The smaller end of the inclusion range includes moderately frequent small quartz, generally angular, along with micas, iron and titanium oxides. The clay microtexture is closely compacted, with little porosity, although a slight honeycomb texture, which has been seen as a feature of more calcareous clays. Individual clay minerals are no longer visible, suggesting that they have formed a continuous liquid phase.

Chemistry: 5th lowest Si, 5th lowest Al, 3rd highest Ca (11.5%), middling through rest.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
3671.1	59.02	17.37	11.58	6.15	2.83	2.12	0.93

Fabric: Indiv.

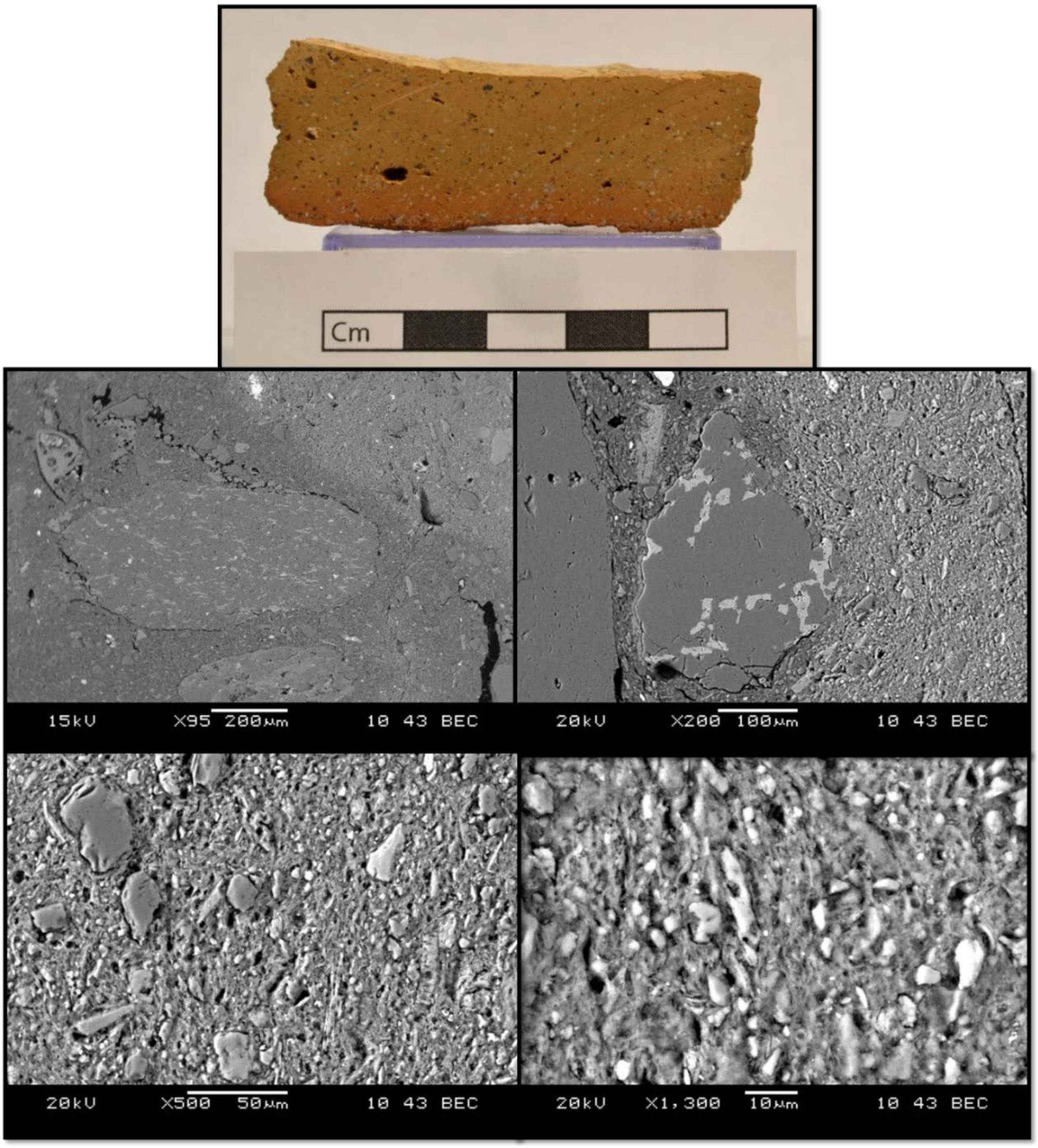


Figure C2. 45: Sample 3671.1 in hand specimen and in SEM backscatter micrographs at x 95, x 200, x 500, and x 1300 magnification.

Catalogue 2.2. Chemical analysis results

Values are means of all bulk area calculations per sample. Data are reported as compound weight % calculated by stoichiometry as oxides, normalised to 100%.

Sample	Compound % SiO_2	Compound % Al_2O_3	Compound % CaO	Compound % FeO	Compound % K_2O	Compound % MgO	Compound % TiO_2
A1	67.9	20.8	0.1	6.6	2.4	1.2	1.1
A2	63.3	20.5	1.0	8.5	3.9	1.7	1.1
A3	63.7	22.7	1.2	7.8	2.6	1.4	0.6
A7	60.4	18.8	5.4	7.7	3.9	3.0	0.8
A8	65.6	20.1	0.6	8.1	3.7	1.4	0.5
B1	67.7	16.6	1.0	7.0	3.7	2.9	1.1
B2	66.9	19.1	0.6	7.5	3.5	1.5	1.0
B3	68.7	18.7	0.3	7.2	3.2	1.2	0.6
B4	64.3	19.5	0.4	8.0	4.0	3.1	0.7
B5	64.1	19.5	1.2	6.8	4.2	3.2	1.0
B6	65.8	18.7	1.2	6.6	3.7	2.9	1.1
E1	70.4	18.3	0.2	5.1	4.0	1.1	0.8
GA6	62.7	23.5	N/D	6.2	5.0	1.5	1.1
GA9	63.2	22.9	0.7	7.0	4.0	1.4	0.9
J1	55.3	20.6	10.6	7.0	4.0	1.9	0.7
LA4	71.6	16.9	0.3	6.2	3.5	1.2	0.3
LA5	66.5	19.7	0.2	7.3	4.5	1.4	0.4
M1	69.1	18.2	1.9	5.2	3.4	1.2	1.0
P1	67.4	19.4	0.2	6.7	4.1	1.4	0.9
X1	68.1	19.4	0.6	6.1	3.7	1.2	0.9
X2	64.5	21.0	0.4	8.3	4.0	1.6	0.2
3152.1	57.4	19.3	10.9	6.1	3.5	2.0	0.8
3152.2	59.5	19.4	4.4	9.1	3.5	2.9	1.1
3152.3	66.8	19.7	1.3	7.4	2.8	1.2	0.7
3213.1	63.7	21.5	1.0	7.3	4.0	1.7	0.9

Sample	**Compound % SiO_2**	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
3213.2	67.7	19.2	0.4	5.8	4.2	1.7	1.0
3367.1	65.0	20.3	0.9	7.2	4.3	1.6	0.8
3415.2	63.1	20.3	1.2	7.8	4.5	2.0	1.0
3416.1	63.4	20.8	1.6	8.0	3.4	1.6	1.1
3416.2	65.7	20.5	1.6	6.9	3.1	1.2	1.0
3416.3	67.2	18.8	0.8	8.6	2.3	1.0	1.2
3416.4	60.6	19.6	7.6	6.5	3.2	1.7	0.9
3471.1	53.6	15.7	19.2	5.7	2.7	2.2	1.0
3471.2	67.2	19.1	0.6	7.2	3.3	1.8	0.8
3471.3	54.5	17.5	16.0	6.1	3.2	1.9	0.9
3471.5	61.8	20.2	1.3	7.6	4.3	3.6	1.3
3477.1	65.7	19.4	4.0	5.5	3.2	1.6	0.8
3477.2	69.8	23.3	2.6	1.7	0.2	0.3	2.1
3658.1	64.8	19.2	1.3	6.7	4.0	3.1	0.9
3658.2	67.5	19.9	0.5	5.6	3.9	1.4	1.3
3658.3	68.3	17.1	1.1	6.7	3.3	2.5	0.9
3658.4	63.1	19.9	1.7	7.1	3.9	3.3	0.9
3671.1	59.0	17.4	11.6	6.2	2.8	2.1	0.9

Table C2. 1: Full SEM EDX CBM chemical analysis results.

	Compound % SiO_2	**Compound % Al_2O_3**	**Compound % CaO**	**Compound % FeO**	**Compound % K_2O**	**Compound % MgO**	**Compound % TiO_2**
Mean	64.6	19.7	2.6	6.8	3.6	1.9	0.9
Std. Dev.	3.9	1.6	3.8	1.2	0.8	0.7	0.3
Coefficient of Variation (%)	6.0	8.0	146.3	17.6	21.1	0.3	0.2
Minimum value	54.5	16.6	0.0	1.7	0.2	3.6	2.1
Maximum Value	71.6	23.5	16.0	9.1	5.0	39.7	31.6

Table C2. 2: Key statistics on the chemical analysis results.

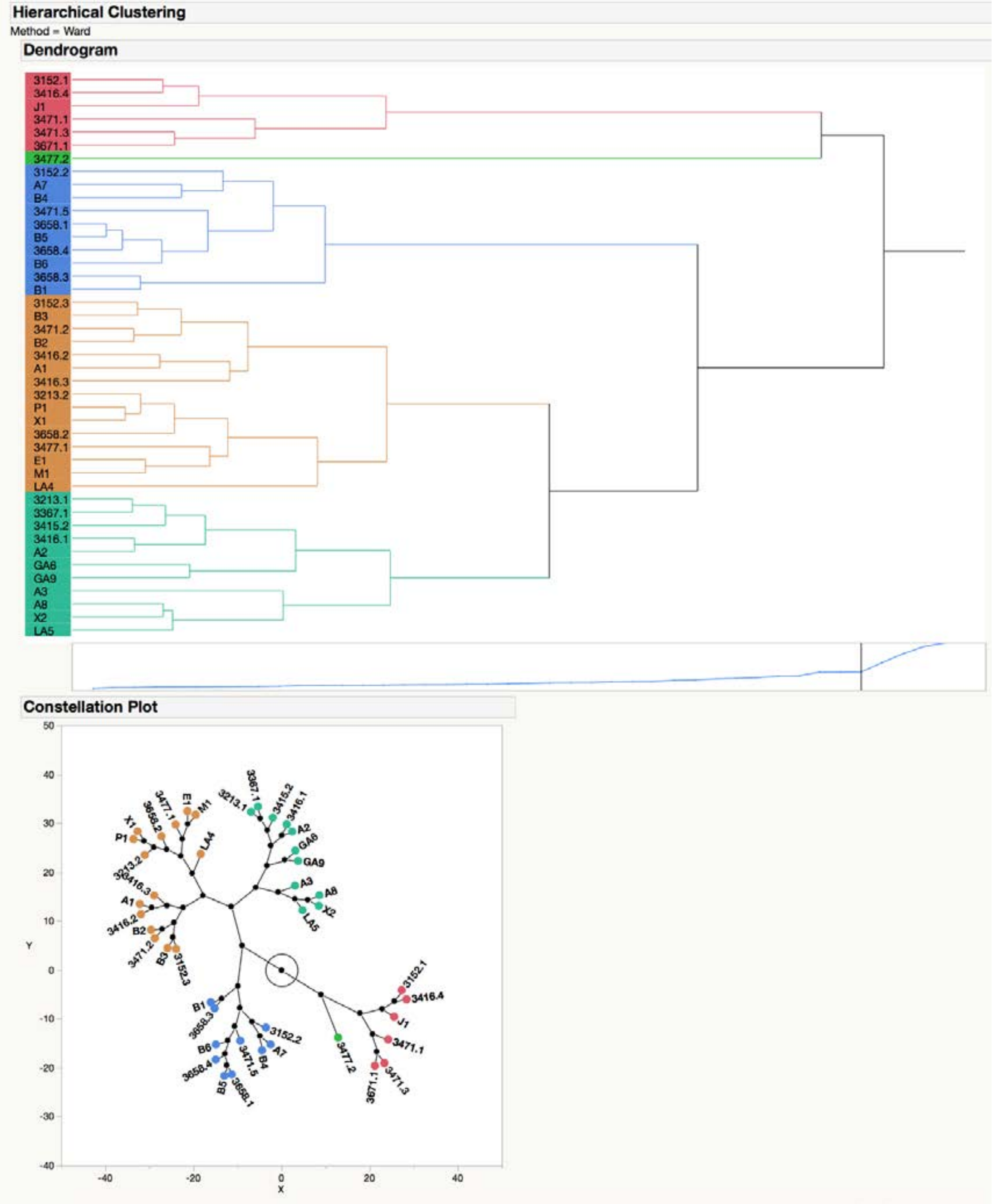
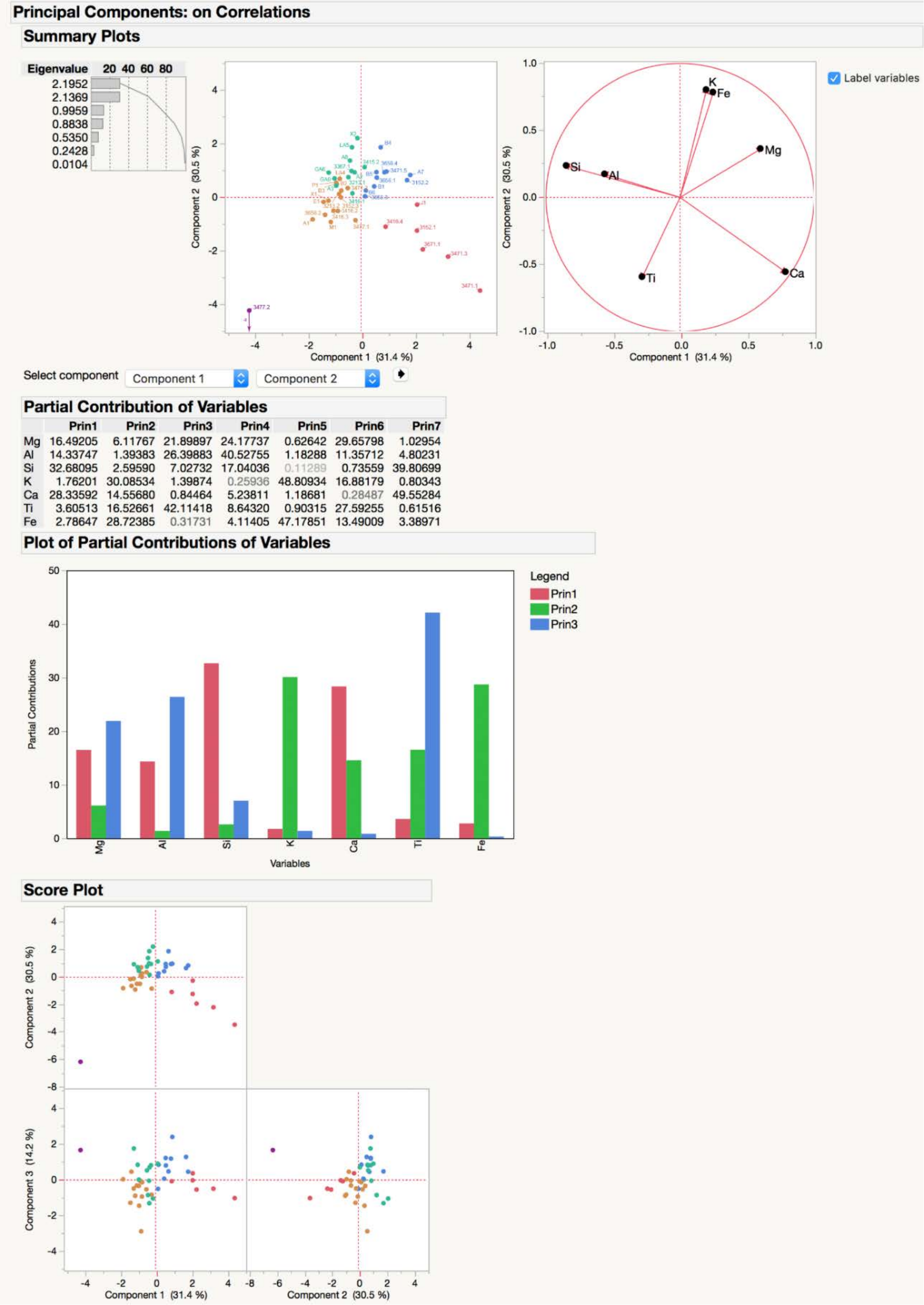


Figure C2. 46: Hierarchical Cluster Analysis of CBM chemical results, using Ward's method.



Principal Components: on Correlations

Summary Plots

Eigenvalue
2.1952
2.1369
0.9959
0.8838
0.5350
0.2428
0.0104

Partial Contribution of Variables

	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6	Prin7
Mg	16.49205	6.11767	21.89897	24.17737	0.62642	29.65798	1.02954
Al	14.33747	1.39383	26.39883	40.52755	1.18288	11.35712	4.80231
Si	32.68095	2.59590	7.02732	17.04036	0.11289	0.73559	39.80699
K	1.76201	30.08534	1.39874	0.25936	48.80934	16.88179	0.80343
Ca	28.33592	14.55680	0.84464	5.23811	1.18681	0.28487	49.55284
Ti	3.60513	16.52661	42.11418	8.64320	0.90315	27.59255	0.61516
Fe	2.78647	28.72385	0.31731	4.11405	47.17851	13.49009	3.38971

Plot of Partial Contributions of Variables

Score Plot

Figure C2. 47: Principal Component Analysis of CBM chemical results.

Catalogue 3. Stone Sample Catalogue

Sample ID: 3095.1

In hand specimen a coarse dark red sandstone, with moderately frequent large rounded grits poorly sorted throughout. Highly friable, practically falling to pieces.

In thin section, a very coarse grained, texturally immature (poorly sorted) sandstone, formed primarily of sub rounded/sub angular large and very large quartz (most often monocrystalline). Also very common rounded, sometimes ovoid, sometimes sub rounded red ferruginous pellets graded to same size fraction as the large sand, perhaps ooliths or peloids. Calcite cement in between, fractured, with remobilisation of iron filling in fractures. Also some larger dark brownish orange clay beads, plus one or two very large degrading limestone fragments and occasional very fine sandstone fragments.

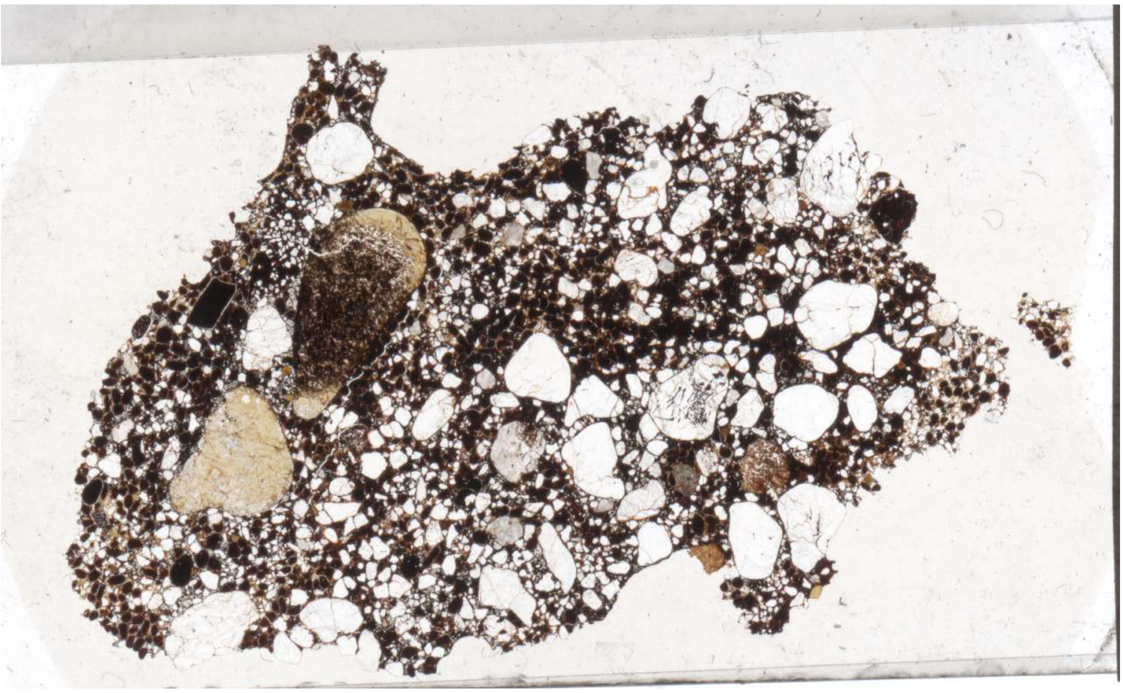


Figure C3. 1: Sample 3095.1 in thin section macrograph.

Sample ID: 3598.1

In hand specimen, a pale yellowish white hard, fine limestone with ooliths and some shell fragments visible.

In thin section, a fine, packed, well sorted oobiomicrite with some sparite cement. Highly abundant small ooliths, bioclasts (predominantly small shell fragments, occasional echinoids and sponge fossils), poorly sorted through the section, held in a predominantly micrite matrix, with occasional sparite. There is infrequent quartz sand, generally small and monocrystalline. Possibly similar to sample 3842.1?

Figure C3. 2: Sample 3598.1 in hand specimen and thin section macrograph.

Sample ID: 3771.1

In hand specimen a coarse mid yellowish grey shelly limestone, with ooliths and bioclasts, some quite large, visible with the naked eye. Some parts of the piece have turned a pinkish grey, perhaps due to heat.

In thin section, a moderately coarse, poorly sorted oobiomicrite. Ooliths are only moderately abundant, generally medium in size, supported in a dominant micrite matrix, with occasional spar. Also present are some large shell fragments, generally bivalves.

Figure C3. 3: Sample 3771.1 in hand specimen and thin section macrograph.

Sample ID: 3785.1

In hand specimen a yellowish highly bioclastic coarse limestone, with blue, green, and black specks and frequent small shell fragments and relatively large ooliths.

In thin section, a coarse oobiosparite, grain supported, dominated by frequent relatively large ooliths, large shell fragments of multiple species (primarily bivalves and echinoids), set within growths of sparite.

Figure C3. 4: Sample 3785.1 in hand specimen and thin section macrograph.

Sample ID: 3799.1

In hand specimen a fine light grey limestone, with few visible clasts except occasional small clusters of shell fragments and ooliths.

In thin section, a very fine well-sorted, matrix supported oobiomicrite, with occasional very small closely packed, shell fragments, and occasional quartz sand and mica.

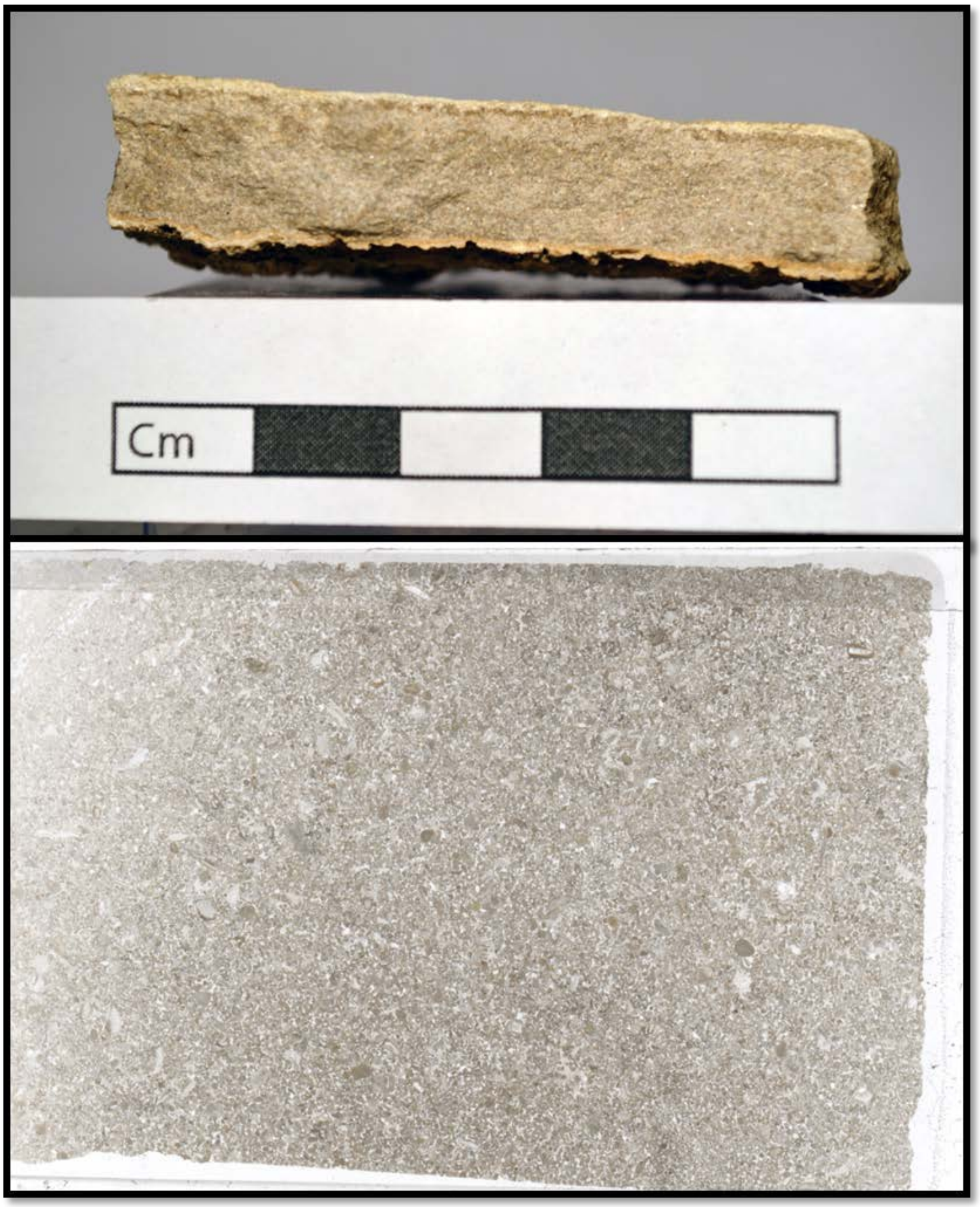


Figure C3. 5: Sample 3799.1 in hand specimen and thin section macrograph.

Sample ID: 3812.1

In hand specimen a very hard fine sandstone, greyish yellow in colour.

In thin section a fine, well-sorted quartz arenite. Abundant very small quartz grains, closely packed, with a small amount of clay, probably micrite matrix. It has only very infrequent small shell fragments.

Figure C3. 6: Sample 3812.1 in hand specimen and thin section macrograph.

Sample ID: 3812.2

In hand specimen a hard brownish yellow coarse limestone, with large ooliths and occasional shell fragments visible.

In thin section, an oobiosparite, with relatively large ooliths and frequent shell fragments, particularly bivalves, set in significant quantities of sparite cement.

Figure C3. 7: Sample 3812.2 in hand specimen and thin section macrograph.

Sample ID: 3842.1

In hand specimen a hard, reddish pink oolitic limestone with occasional small shell fragments.

In thin section a packed oobiomicrite, with generally small ooliths, fossils and shell fragments set in sparite, plus occasional small sand grains. There is a clear change in one side of the section, moving from this finer texture to a somewhat coarser texture, with larger intraclasts. Possibly similar to sample 3598.1, simply colour altered by heat?

Figure C3. 8: Sample 3842.1 in hand specimen and thin section macrograph.

Sample ID: 3842.2

A dark grey and white limestone with frequent ooliths, some shell fragments, and occasional dark bluish black shiny clasts.

In thin section, a very coarse oobiosparite with large ooliths and shell fragments, set in large intergrowths of sparite – this is by far the most sparry sample examined.

Figure C3. 9: Sample 3842.2 in hand specimen and thin section macrograph.