Verulamium Region White Ware production at the Roman kiln site of Brockley Hill, Middlesex: a compositional and technological reassessment

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1. Introduction

The recent discovery of a Roman kiln site dated to the second century AD at Northgate House in the present day City of London (Seeley and Drummond-Murray 2005) has begun to alter the view of pottery production and distribution in and around Roman London. The kiln site at Northgate House (Fig 1a) produced a range of material, including sandy, light-coloured, functional pottery that closely matches Verulamium Region White Ware (VRW) (Fig 2). Production of this common Roman coarse ware was previously thought to have been restricted to workshops of the Verulamium region pottery industry, which was located between Stanmore and St. Albans, north-west of London (Fig 1a). However, evidence for the manufacture of pottery types resembling VRW within London clearly calls for a reassessment of this class of pottery and its circulation in Roman Britain (Fig 1b).

In the present study we revisit Brockley Hill (Fig 1a), the most extensively excavated kiln site of the Verulamium region pottery industry, and examine the production of its two main VRW outputs, mortaria and flagons (Fig 2). We apply a combination of thin section petrography and geochemical analysis to a large assemblage of sherds in order to investigate in detail the composition, raw materials and manufacturing technology of VRW at this important site. By analysing well-dated groups of pottery from numerous contexts at Brockley Hill we have characterised the compositional variability of VRW ceramics both within and between all five phases of operation of the kiln site. These signals have been interpreted in terms of possible technological, organisational and social phenomena related to Roman pottery production.

We have compared our data on Brockley Hill VRW with published analyses of macroscopically similar pottery excavated from Northgate House (Tomber 2001; Vince 2002a; 2002b; Vince and Tomber 2005) in order to address the suspected links between these two workshops and identify possible characteristics that may be used to distinguish their respective products at other sites in Roman Britain.

2. Brockley Hill and the Verulamium Region Pottery Industry

Between *c* AD 50 and AD 170 a large pottery industry developed along Watling Street between Londinium and Verulamium (Fig 1a). The Romano-British kiln sites situated in this area, which are collectively referred to as the Verulamium region pottery industry, include Verulam Hills Field (Anthony 1968), Radlett (Castle 1974a), Little Munden (Saunders and Havercroft 1977) and Brockley Hill (Applebaum 1951; Castle 1972a). The Verulamium region industry manufactured Romanized shapes that were introduced in Britain after the Roman conquest. It quickly became one of the major suppliers of coarse pottery to London and other settlements in south-east England between the late first and early second centuries AD (Fig 1b) (Swan 1984, 97).

The principal products of the Verulamium region pottery industry were flagons and mortaria (Fig 2) but other forms such as bowls, lids, jars, lamps, amphorae and tazzas were also produced. The most common pottery type is Verulamium Region White Ware (VRW), which has a cream or off-white colour and a hard fabric characterised by a dense, clean clay matrix and abundant well-sorted quartz inclusions (Tomber and Dore 1998, 154). Other pottery types produced by the Verulamium region industry include Brockley Hill White-slipped Ware, Verulamium Region Grey Ware, Verulamium

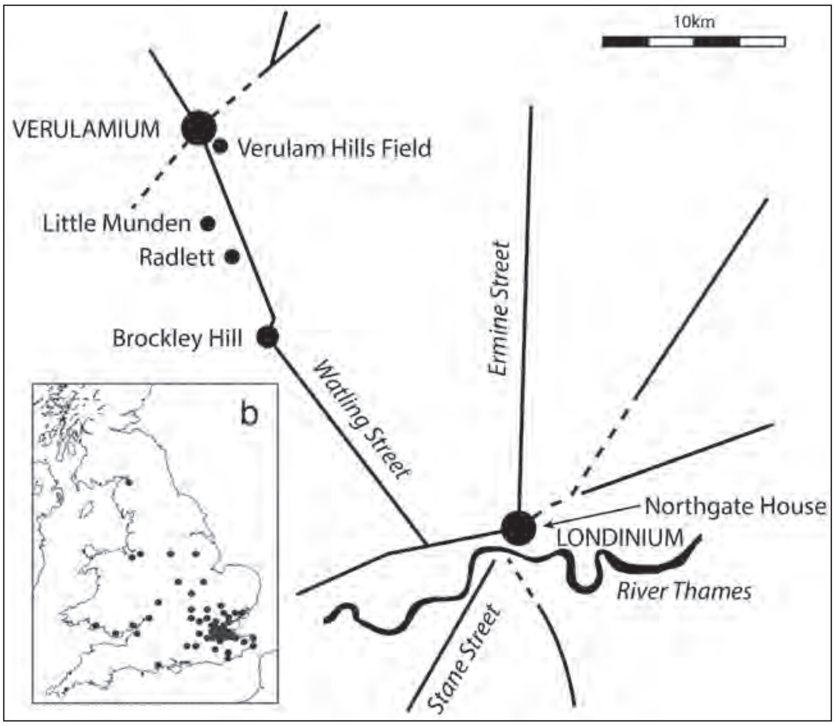

Fig 1. a). Location of workshops belonging to the Verulamium region pottery industry, including Brockley Hill, and the location of the kiln site of Northgate House in the Walbrook valley, London (modified from Seeley and Thorogood 1994, 224, fig 2); b). The known distribution of VRW pottery in Britain (modified from Tyers 1996, 201, fig 256)

Region Mica-dusted Ware, Verulamium Region Marble Ware and Verulamium Region Coarse White-slipped Ware.

One of the largest and most extensively excavated kiln sites within the Verulamium region pottery industry is Brockley Hill, situated near Stanmore on the north-western edge of present-day London (Figs 1a and Fig 3). Brockley Hill was excavated between 1937 and 1955 (Cottrill 1937; Richardson 1948; Applebaum 1951; Suggett 1954; 1955; 1956) and between 1968 and 1975 (Castle 1972a; 1972b; 1973a; 1973b; 1974b; 1975; 1976; 1978; Castle and Warbis 1973). Initial excavations attempted to determine whether Brockley Hill was the site of *Sulloniacae*, mentioned in the Antonine Itinerary, and to detect the location of Roman Watling Street in this area. They unearthed important groups of early Flavian pottery, including bowls, flagons, jars, amphorae and mortaria. The later excavations, which were undertaken in advance of the building of a hospital, encountered several kilns dating from different phases of pottery manufacture at Brockley Hill. These revealed that pottery was being produced from *c* AD 50 (pre-Flavian period) until *c* AD 150 (early Antonine period), when a drop in production appears to have taken place. It has been suggested that the discovery of stamped pottery in excavations from 1973 and 1975 (Castle 1975; 1976; 1978), provides evidence for the movement of potters between Brockley Hill and other Romano-British kiln sites (Swan 1984, 98).

Excavations in present day Moorgate, London, between 1999 and 2000 uncovered evidence for a second century AD Roman kiln site in what would have been the Upper Walbrook valley (Seeley and Drummond-Murray 2005). This appears to have manufactured a range of pottery including some Romanized styles such as VRW flagons and mortaria. The discovery of this site strongly implies that VRW was produced over a much wider area than previously thought. It calls for a reassessment of the supply of this common pottery type to London and other Roman settlements in Britain (Fig 1b).

3. Previous Analytical Studies of VRW

Pottery of the Verulamium region industry, particularly VRW, has been the subject of previous detailed compositional investigation (Devereux *et al* 1982; Tomber 2001; Vince 2002a; 2002b; Vince and Tomber 2005). Devereux *et al* (1982) analysed geochemically 92 VRW samples from the production sites of Brockley Hill, Verulam Hills Field, Radlett and Little Munden (Fig 1a) via X-ray fluorescence spectrometry. Their data revealed the existence of seven geochemical groups of VRW, which related well to the pottery of the different sites. This may be explained by the exploitation of specific local clay sources at the various sites within the Verulamium region pottery industry. The presence of three separate compositional groups among the sherds analysed from

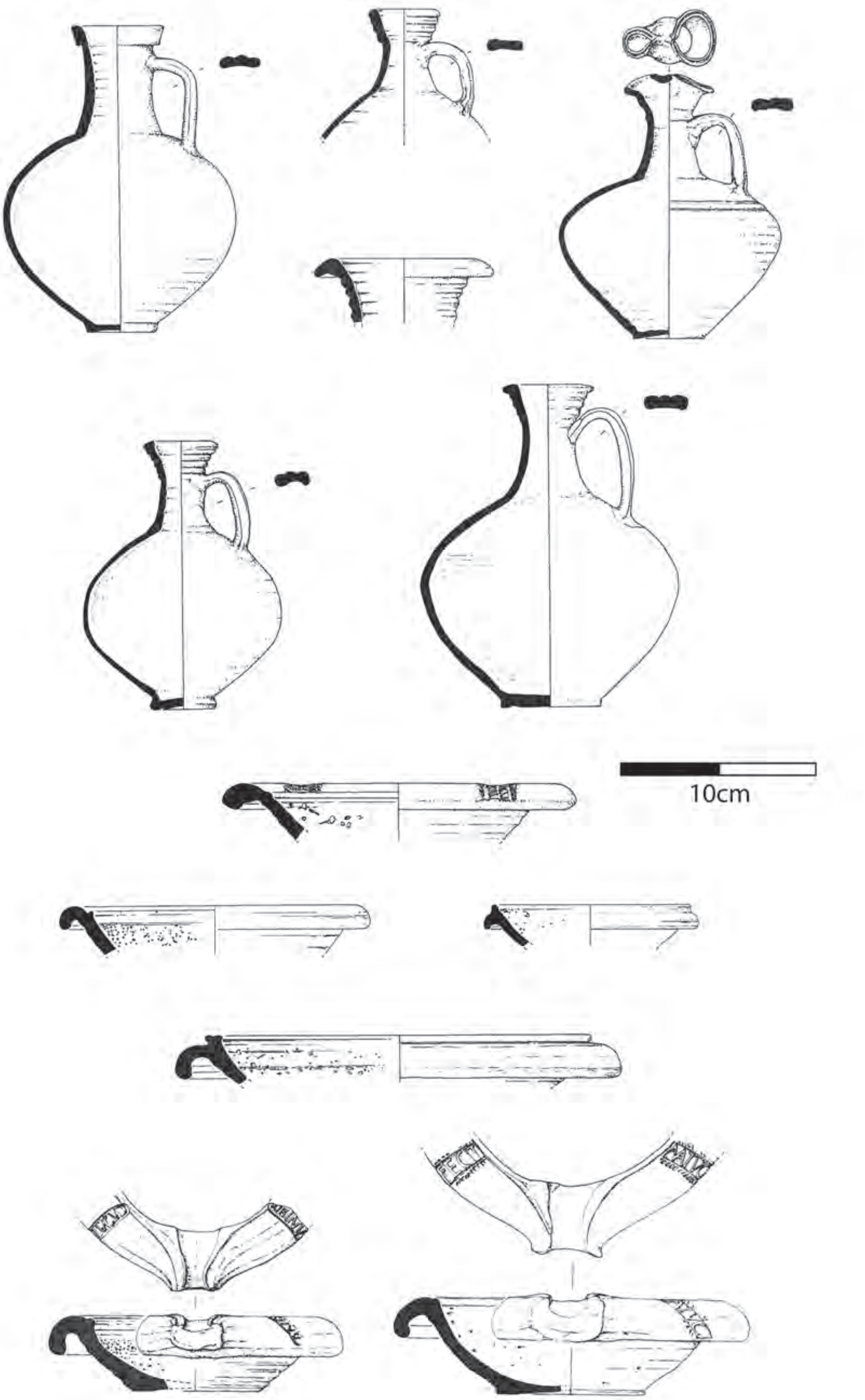

Fig 2. Pottery vessels of Verulamium Region White Ware: flagons (top) and mortaria (bottom), (modified from Davies et al 1994, 43–4, 49–50, figs 34, 35, 39 and 40)

Brockley Hill and two from Verulam Hills Field might also imply the existence of several clay paste recipes at single production sites that could be related to different vessel forms, the activities of specific potters and/or changes in pottery raw materials and technology over time. Unfortunately, the strictly geochemical approach taken by Devereux *et al* (1982) and the lack of temporal scale in their sampling strategy means that it is not possible to assess the likelihood of these possibilities.

In an attempt to investigate the link between the Verulamium region pottery industry and the newly discovered VRW production remains from the Upper Walbrook valley, Vince and Tomber (2005) (see also Tomber 2001; Vince 2002a; 2002b) compared samples of VRW from Northgate House and Brockley Hill both petrographically and geochemically. They were specifically interested in whether the close macroscopic similarity between the VRW ceramics of these two sites was due to the transportation of clay from Middlesex to London, the use of another similar light-firing clay source at Northgate House, or the result of clay preparation (Vince and Tomber 2005, 174). Fourteen VRW samples were analysed in thin section, five from Brockley Hill and nine from Northgate House (Tomber 2001). Sixteen VRW samples were also analysed via inductively coupled plasma mass spectrometry (ICP-MS), 11 from Brockley Hill and five from Northgate House. Other Roman pottery wares from Northgate House were included in their analysis, as well as samples of clay used for the lining of kilns at the two sites.

The analysis of Vince and Tomber (2005) indicated that most VRW samples from Brockley Hill and Northgate House were petrographically very similar, containing sand inclusions of a comparable composition. The majority of the samples also grouped together in a principal components analysis (PCA) scatterplot of the ICP-MS results (Vince and Tomber 2005, fig 181, 176), indicating their close geochemical composition. This suggested to Vince and Tomber (2005, 175) that ‘a clay of exactly the same type as that used at Brockley Hill and quite likely to be from the same source’ was used for the production of VRW at Northgate House. Nevertheless, several VRW samples from Northgate House were found to have a different chemical composition from the rest of the sherds. These could not be distinguished macroscopically or petrographically from the other VRW samples. However, Vince and Tomber (2005, 175) hypothesised that they were made with the addition of an unspecified, locally-sourced, red-firing clay. By re-examining their scatterplot, it is possible to see that three of the 11 VRW sherds from Brockley Hill also plot away from the main geochemical group. This supports the findings of Devereux *et al* (1982) that several compositional groups of VRW pottery exist at Brockley Hill. The same may be said for Northgate House VRW, suggesting that this class of pottery is not as compositionally homogeneous as previously thought.

With the above in mind, further compositional analyses are clearly required before it will be possible to distinguish between the products of Brockley Hill, Northgate House and other kiln sites producing VRW and understand the supply and demand of this important Roman pottery type. In the present study we have examined a large well-dated assemblage of sherds from Brockley Hill with the aim of reconstructing aspects of VRW production at this site. This dataset has also been used to further investigate the possible compositional and technological similarities and differences between Brockley Hill and Northgate House VRW that were highlighted by the previous analyses described above.

4. Sample Material and Analytical Methods

A total of 50 VRW sherds from Brockley Hill were subjected to detailed petrographic and geochemical analysis (Table 1). A sampling strategy was devised that covered the complete operational period of the kiln site (*c* AD 50–150) and the main VRW shapes that were produced. It was decided to concentrate on materials from the 1968–1975 excavations (Castle 1972a; 1972b; 1973a; 1973b; 1974a; 1975; 1976; 1978; Castle and Warbis 1973) due to their better contextual information. This material, which is housed at the London Archaeological Archive and Research Centre (LAARC), comes from six contexts that can be ascribed to five successive phases of the kiln site (Fig 3; Table 1). Some doubt surrounds the nature of Context 6 which is dated to the middle of the second century AD. It is not clear whether pottery was still being produced at this point in the early Antonine period.

Flagons and mortaria (Fig 2) were the dominant pottery forms produced at Brockley Hill in Roman times. Five representatives of each of these shapes were selected from each of the five phases (Table 1). This provided a framework within which to examine the composition and production technology of these two styles of pottery over time at the site. In the case of Phase 3, the mortaria and flagons come from different contexts (Table 1). Unfortunately, it was not possible to analyse samples of stamped pottery or relate the studied sherds to stamped pieces found at the site.

All samples were analysed by a combination of thin section petrography and bulk geochemistry. Standard 30μm thin sections were prepared from each sherd in a vertical orientation through the vessel wall (Whitbread 1996, 415, fig 1). These were examined under the polarising light microscope at magnifications of ×25–200 and studied in terms of the composition, shape and texture of their particulate inclusions, the nature of their clay matrix and the shape, size and arrangement of their voids. An attempt was made to group the thin sections into petrographic fabrics based on these visual observations (Quinn 2013, 73–9). The 50 thin sections were compared under the microscope with the Brockley

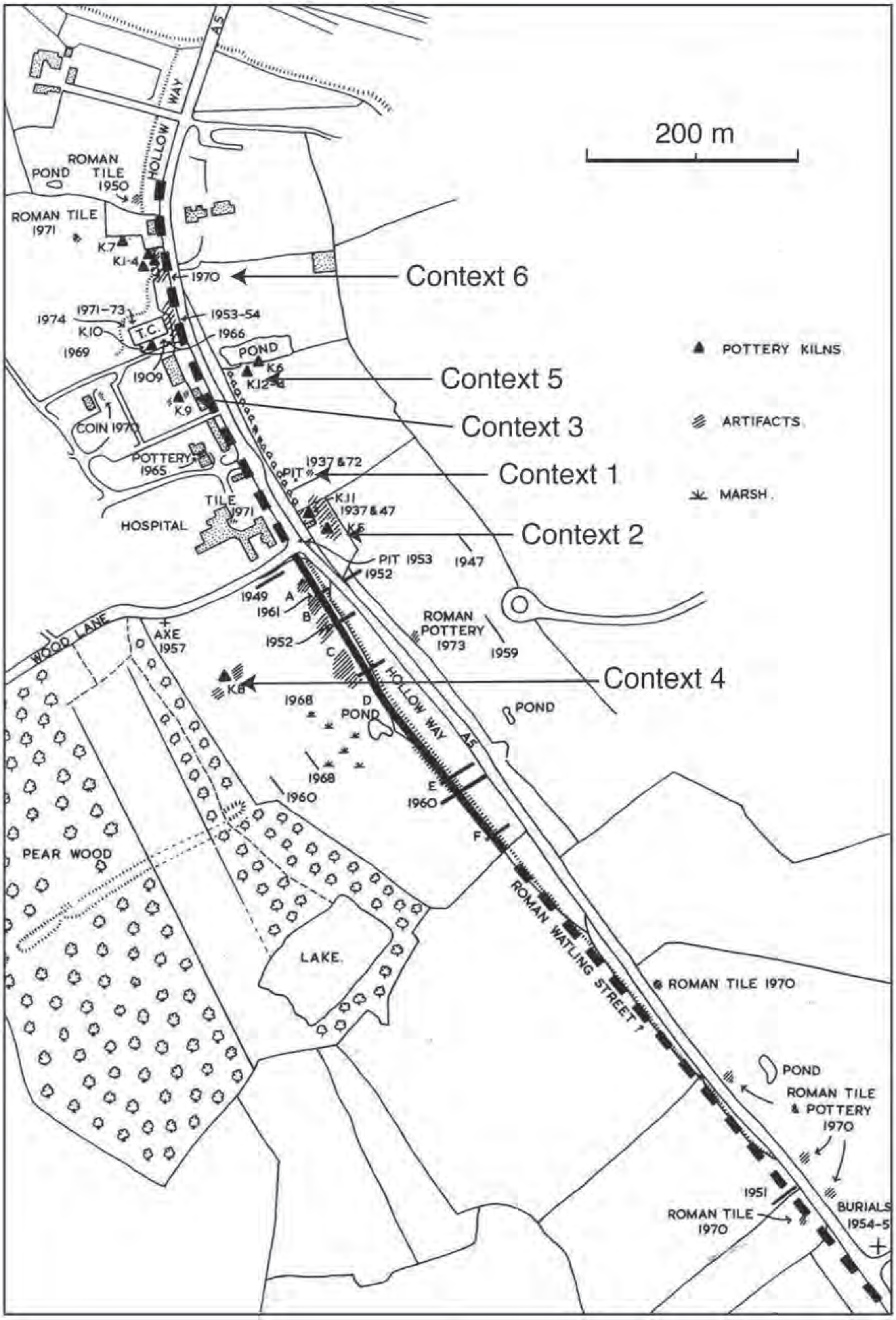

Fig 3. Plan of the Roman kiln site of Brockley Hill indicating the contexts from which the 50 VRW sherds analysed in this study (cf Table 1) originated (modified from Castle 1976, 207, fig 1)

Table 1. Details of the 50 VRW ceramic sherds analysed from Brockley Hill in this study.

<table>
<tr><th>Context No.</th><th>Details</th><th>Sampled Form</th><th>Phase</th><th>Period</th></tr>
<tr><td>6</td><td>Site A 1970: Layers 3 and 3a</td><td>5 Flagons,
5 Mortaria</td><td>5</td><td rowspan="4">Early second century – Antonine (c AD 97–160)</td></tr>
<tr><td>5</td><td>Site C: Kiln 2</td><td>5 Flagons,
5 Mortaria</td><td>4</td></tr>
<tr><td>4</td><td>Kiln 8: Kiln ditch</td><td>5 Flagons</td><td rowspan="2">3</td></tr>
<tr><td>3</td><td>Doinus Kiln: Furnace infill</td><td>5 Mortaria</td></tr>
<tr><td>2</td><td>Site A: Trench 1, pit layer 2</td><td>5 Flagons,
5 Mortaria</td><td>2</td><td>Flavian (c AD 69–96)</td></tr>
<tr><td>1</td><td>Site B: Trench 2, pit</td><td>5 Flagons,
5 Mortaria</td><td>1</td><td>Pre-Flavian (c AD 50–69)</td></tr>
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Hill and Northgate House VRW thin sections analysed by Tomber (2001) and Vince and Tomber (2005) to ascertain their petrographic similarities and differences.

Due to the homogeneous, quartz-rich, nature of the Brockley Hill VRW samples, visual classification into well-defined fabrics was challenging. For this reason, quantitative petrographic data was also collected from the 50 thin sections, including the relative abundance of inclusions, matrix and voids, as well as the composition and size of the inclusions. Modal and textural data were collected using a point counting device connected to the polarising light microscope (Quinn 2013, 102–11). A total of 100 points were counted per thin section using the single-intercept method and a spacing of 1mm, which was roughly equivalent to the size of the largest inclusions in the samples. The raw quantitative data were analysed statistically to determine the relative abundance of specific classes of inclusions as well as textural parameters including the mode, mean, standard deviation and grain size distribution of the inclusions (Table 2).

All VRW sherds were also analysed geochemically via energy dispersive X-ray fluorescence (ED-XRF) using a subsample *c* 8g in weight. The surface of each sample was cleaned with a tungsten carbide drill bit to remove possible contaminants. It was then crushed to a fine powder in a percussive ball mill, dried overnight at 110°C and pressed into a disc with 0.9g of binding wax at a pressure of 15 tonnes. The pressed pellets were analysed with a 'Spectro X-Lab 2000' ED-XRF to determine the abundance of 50 elements. All elements were calculated as oxides by stoichiometry. Major elements were expressed as weight percent and minor and trace elements were recorded as parts per million (ppm). The accuracy and precision of the ED-XRF analysis were determined by running two certified reference materials 'NBS 679 Brick Clay' and 'SARM 69 Ceramic 1'. Elements with an abundance below the limits of detection of the machine (*c* 20ppm) were disregarded before submitting the geochemical dataset to multivariate statistical analysis.

Principal components analysis (PCA) was employed to detect possible geochemical groups within the 50 VRW samples that might be of archaeological significance. The results of the visual petrographic grouping, the quantitative analysis of inclusions and the geochemical classification of the samples were compared to one another, as well as with information on the shape of each sherd (flagon or mortarium) and the phase of operation of Brockley Hill from which it came.

In order to identify the possible sources of clay and temper used for the production of VRW at Brockley Hill, a program of raw material prospection and analysis was carried out in the landscape surrounding the site. Using a geological map and accompanying reports (Sumbler 1996) as a guide, attempts were made to identify and sample specific deposits of clay, rock and sand that form the Cretaceous and Tertiary bedrock of the area (Fig 4). Particular efforts were made to sample the 'light firing clay' referred to by Vince and Tomber (2005, 175). Due to extensive modern development in this part of London it was not always possible to access the underlying geology. A total of nine field samples were collected (Fig 4; Table 3) and processed in the laboratory. Eight clay-rich samples were dried, crushed, sieved, wetted, formed into briquettes and fired at 900°C for one hour in an electric kiln. A single sandy sample of possible temper was mounted in epoxy resin. All field samples were thin sectioned and compared with the VRW ceramics under the microscope in order to identify matches.

5. Petrographic and Geochemical Composition of Brockley Hill VRW

The 50 thin sections of VRW analysed from Brockley Hill are characterised under the microscope by the presence of equant and elongate, sub-angular to rounded, coarse sand to coarse silt-sized mono- and polycrystalline quartz inclusions, plus less frequent inclusions of chert, feldspar, white mica and opaque minerals (Fig 5). Significant variation exists in terms of the abundance, sorting and size of the quartzose inclusions, with some samples characterised by abundant coarse silt and fine sand-sized inclusions (Fig 5a) and others by less abundant medium sand-sized inclusions (Fig 5b). The clay matrix

Table 2. Quantitative thin section petrographic data on the 50 VRW ceramic sherds analysed from Brockley Hill in this study. Samples are arranged by phase of operation of the kiln site and vessel shape (F: flagon; M: mortarium).

Sample	Shape	Phase	Total Inc.	Quartz	Poly-quartz	Chert	Clay Pellets	Maximum	Mean	Mode	Standard Deviation
BHC001	M	1	27	92.6	7.41	0	0	0.44	0.26	0.28	0.095
BHC002	M	1	27	92.6	7.41	0	0	0.48	0.24	0.16	0.123
BHC003	M	1	35	97.1	0	0	2.86	0.8	0.27	0.28	0.143
BHC004	M	1	19	89.5	10.5	0	0	0.6	0.31	0.28	0.118
BHC005	M	1	33	97	3.03	0	0	0.56	0.24	0.16	0.133
BHC006	F	1	30	100	0	0	0	0.64	0.25	0.12	0.141
BHC007	F	1	26	92.3	3.85	0	3.85	0.4	0.22	0.16	0.094
BHC008	F	1	43	100	0	0	0	1	0.31	0.28	0.162
BHC009	F	1	52	88.5	11.5	0	0	0.48	0.24	0.28	0.110
BHC010	F	1	34	100	0	0	0	0.6	0.3	0.28	0.146
BHC011	M	3	45	93.3	6.67	0	0	0.56	0.25	0.28	0.107
BHC012	M	3	39	94.9	5.13	0	0	0.52	0.17	0.12	0.101
BHC013	M	3	34	94.1	5.88	0	0	0.52	0.23	0.2	0.097
BHC014	M	3	36	91.7	5.56	0	2.78	0.6	0.29	0.4	0.128
BHC015	M	3	48	97.9	2.08	0	0	0.48	0.22	0.2	0.094
BHC016	F	2	21	100	0	0	0	0.48	0.27	0.32	0.103
BHC017	F	2	9	100	0	0	0	0.32	0.2	0.2	0.09
BHC018	F	2	25	96	4	0	0	0.48	0.25	0.16	0.10
BHC019	F	2	28	96.4	3.57	0	0	0.4	0.27	0.4	0.107
BHC020	F	2	28	96.4	0	3.57	0	1	0.26	0.28	0.172
BHC021	M	2	50	100	0	0	0	0.68	0.26	0.28	0.117
BHC022	M	2	42	100	0	0	0	0.56	0.27	0.2	0.115
BHC023	M	2	46	95.7	4.35	0	0	0.68	0.24	0.28	0.110
BHC024	M	2	43	97.7	2.33	0	0	0.48	0.25	0.28	0.097
BHC025	M	2	26	96.2	3.85	0	0	0.52	0.27	0.2	0.109
BHC026	M	4	41	100	0	0	0	0.48	0.2	0.12	0.085
BHC027	M	4	55	100	0	0	0	0.48	0.25	0.28	0.089
BHC028	M	4	40	95	5	0	0	0.4	0.22	0.24	0.07
BHC029	M	4	56	94.6	5.36	0	0	0.52	0.23	0.2	0.091
BHC030	M	4	49	100	0	0	0	0.64	0.25	0.12	0.131
BHC031	F	4	38	92.1	7.89	0	0	0.64	0.34	0.4	0.108
BHC032	F	4	25	96	4	0	0	0.6	0.21	0.24	0.134
BHC033	F	4	28	96.4	3.57	0	0	0.52	0.22	0.08	0.134
BHC034	F	4	29	100	0	0	0	0.52	0.24	0.28	0.101
BHC035	F	4	11	100	0	0	0	0.32	0.22	0.2	0.068
BHC036	F	3	31	96.8	3.2	0	0	0.48	0.18	0.12	0.09
BHC037	F	3	47	100	0	0	0	0.8	0.26	0.28	0.145
BHC038	F	3	40	98	3	0	0	0.44	0.24	0.24	0.092
BHC039	F	3	55	100	0	0	0	0.48	0.25	0.28	0.080
BHC040	F	3	44	95.5	4.55	0	0	0.52	0.2	0.28	0.103
BHC043	M	5	48	89.6	10.4	0	0	0.4	0.19	0.12	0.079
BHC044	M	5	53	96.2	3.77	0	0	0.32	0.15	0.12	0.069
BHC045	M	5	45	97.8	2.22	0	0	0.48	0.17	0.08	0.125
BHC046	M	5	52	100	0	0	0	0.28	0.11	0.12	0.062
BHC047	M	5	42	100	0	0	0	0.4	0.12	0.08	0.088
BHC048	F	5	46	93.5	6.52	0	0	1	0.25	0.12	0.175
BHC049	F	5	29	100	0	0	0	0.48	0.27	0.16	0.108
BHC050	F	5	43	100	0	0	0	0.2	0.09	0.08	0.042
BHC051	F	5	35	100	0	0	0	0.52	0.2	0.08	0.128
BHC052	F	5	41	95.1	4.9	0	0	0.48	0.2	0.12	0.095

is generally light-coloured (Fig 5c), but in numerous samples can be more reddish (Fig 5d) and intermediate shades exist between these two extremes. Many samples contain distinctive red streaks and clay pellets (Fig 5e), grey-black mottling that stands out against the otherwise light-coloured clay matrix (Fig 5f), as well as iron-rich nodules (Fig 5g). The samples have variable porosity with some almost lacking in voids and others containing large vughs and elongate voids that can be aligned to the margins of the parent vessel (Fig 5h).

Fig 4. Simplified geological map of the area surrounding Brockley Hill with the location of the nine field samples of potential ceramic raw materials collected for comparison with the VRW sherds in this study

The gradational nature of the variation in the Brockley Hill VRW ceramics in thin section means that end members can appear petrographically and texturally quite different (Fig 5a–d), but are linked by thin sections with a continuous range of intermediate compositions. With the exception of several samples with more abundant, silt-sized inclusions, rare white mica and a more reddish clay matrix, that includes BHC043, 044, 045, 046, 047, 048, 050 and 052 (Figs 5a and 6g), this variation makes the assemblage difficult to sub-divide into meaningful petrographic groups using a qualitative, visual approach. With this in mind, the quantitative point-count data collected from all thin sections (Table 2) provides a more accurate means of detecting and characterising compositional patterns in terms of the abundance and size of inclusions in the VRW sherds.

Based on a count of 100 points per thin section, the proportion of inclusions varies from as low as 9% to a maximum of 55% (Table 2). All samples were dominated by monocrystalline quartz, which accounts for 90% or more of the inclusions encountered. In addition, low but significant numbers of polycrystalline quartz inclusions (<10%) and less frequent clay pellets and chert (<5%) occur in some samples.

The mean (0.09–0.34mm) and modal inclusion size (0.08–0.32mm), as well as the standard deviation (0.04–0.18 mm), differ significantly between samples (Fig 7), confirming the textural variability detected visually (Figs 5 and 6). Comparing these data to the shape of each sherd (flagon or mortarium) and the phase of operation of Brockley Hill from which it came reveals some interesting patterns (Table 2). For example, mortaria from Phase 1 (pre-Flavian period) (Fig 5c) and flagons from Phase 2 (Flavian period) (Fig 5d) contain less inclusions than the other samples, whereas mortaria from

Table 3. Details of the nine field samples of potential ceramic raw materials collected in the region around Brockley Hill and compared with the VRW sherds in this study. For the location of the samples see Fig 4.

Field Sample	Location	Geological Deposit	Description
1	Ditch cut on A5	London Clay Formation	Grey clay
2	Fallen tree	Stanmore Gravel Formation	Loose sand and gravel
3	Ditch cut on Wood Lane	Claygate Member	Grey clay
4	House foundations	London Clay Formation	Grey clay
5	Disused brick pit	Lambeth Group	Light-coloured clay
6	Disused brick pit	Lambeth Group	Light-coloured clay
7	Ditch cut on A5	London Clay Formation	Yellowish clay
8	Ditch cut on A5	London Clay Formation	Yellowish clay
9	River bank	Recent alluvium	Grey clay

Phase 5 (early Antonine period) (Figs 5a and 6g) have more inclusions. The dominant (modal) inclusion size in the samples (Table 2) reveal that mortaria and flagons from Phase 5 also have a particularly fine overall grain size due to a greater proportion of silt-sized inclusions (Figs 5a and 6g).

Of the 50 elements recorded by ED-XRF analysis, Ag, As, Bi, Br, Cd, Cs, Ge, Hf, Hg, I, In, Mo, Se, Sn, Sb, Ta, Te, Th, Tl and U were present in abundances that are below the limits of detection of the machine and were therefore left out of subsequent statistical analyses. The elements Co and W were not included due to potential contamination from the drill bit used to clean the samples. The elements Ba, Cl, P and S were left out as they can be affected by post-depositional alteration of ceramics. The measurement of Na was deemed to be too inaccurate for inclusion in the statistical analysis.

The concentration of the remaining 23 elements (Table 4) provides a detailed geochemical picture of VRW produced at Brockley Hill. All samples contain abundant silica (SiO_2), which derives mainly from the quartzose inclusions in the ceramics and varies according to the proportion of this aplastic material from *c* 65% (eg Sample BHC017, Fig 5d) to *c* 80% (eg Sample BHC029, Fig 6a). The next most abundant component is alumina (Al_2O_3), which makes up *c* 15–30% of the bulk composition of the ceramics and mainly reflects differences in their clay mineral chemistry. Samples with the highest alumina are characterised by light-firing clay matrices (eg Sample BHC005, Fig 5c) and those with the lowest levels have a more reddish clay fraction (eg BHC046, Fig 6g). The proportion of iron (III) oxide (Fe_2O_3) varies from *c* 1.5–5% and affects the colour of the clay fraction of the ceramics in an opposite manner, with the iron-rich samples having darker, more reddish matrices (eg Sample BHC035, Fig 5e) and the relatively iron-poor VRW being characterised by lighter coloured clay (BHC029, Fig 6a). Lime (CaO) constitutes <1% of all samples, which is in keeping with the samples' non-calcareous clay matrices and the absence of carbonate inclusions or calcium-bearing feldspars. Other minor elements include K_2O, TiO_2 and MnO. Elements detected in trace quantities (<0.1%) in the VRW ceramics include Ba, Ce, Cr, Cu, Ga, La, Nb, Ni, Rb, St, V, Y, Zn and Zr.

In order to classify the 50 VRW sherds based on their elemental composition and detect possible geochemical groups the dataset of 23 elements was subjected to multivariate statistics via PCA. The extreme dominance of silica in the samples means that variation in this compound, which is related to abundance of quartzose inclusions in the samples, is likely to exert a strong dilution effect on the relative proportion of the other elements (Baxter and Freestone 2006, 524). In an attempt to compensate for this effect, the data were initially log-transformed prior to statistical classification. However, important compositional patterning that was discovered by performing PCA on the normalised, non-log transformed data (Fig 8) was not visible, so log-transformation was not used in the final classification of the samples.

A scatterplot of first two principal component scores for the 50 VRW samples reveals three compositional groupings, as well as one outlier (Fig 8a; Table 4). A factor plot of the contribution of each of the 23 elements to the first two principal components (Fig 8b), confirms the strong influence of silica on principal component 1, as well as the negative correlation of numerous other elements, including Al, Cr, K, Rb and Sr, with Si. Several trace elements including Ce, Ga, La and Y are also significant for the classification of the samples, particularly for the separation of the sherds in chemical group 3 (Fig 8f).

Groups 1 and 2 do not exhibit any clear relationship to either the vessel shape of the samples (Fig 8c), nor the phase of Brockley Hill from which they came (Fig 8d). However, it is worth noting that the four samples that constitute chemical group 3 are all flagons from phase 4 of the site.

The 50 VRW thin sections were re-examined in the light of the geochemical classification. Chemical group 1 contains the eight VRW sherds with abundant silty inclusions and a reddish clay matrix (Figs 5a and 6g). However, other samples that are petrographically quite different to these were also classified in this group (eg Figs 5b and 6a). Chemical group 2 is equally diverse in thin section (eg Fig 5c, h and g). The four samples that constitute chemical group 3 all have a reddish clay matrix with streaking and/or pellets, as well as sparse medium sand-sized quartzose inclusions (Fig 5e). While they are petrographically closely related to one another, red streaking is also present in some samples classified in chemical group 2. The distinctive dark mottling (Fig 5f) is present in samples belonging to all three chemical groups, perhaps suggesting that it may represent some sort of contamination during thin section preparation. Sample BHC017, which represents an outlier in the PCA plot in Fig 8a is characterised by a reddish clay matrix and only very sparse sand inclusions (Fig 6d). In this latter respect it is unlike the other 49 VRW samples analysed.

A comparison between the quantitative point count data and the geochemical groupings reveals the strong influence of the abundance of quartzose inclusions on the chemical classification of the samples (Fig 8e). All but one of the sherds within chemical group 1 contain >31% of inclusions, whereas all the samples classified in chemical group 3 and most of those in chemical group 2 have 11–30% inclusions. The outlier sample BHC017 has the lowest percentage of inclusions which is in keeping with its position on the plot in Fig 8e. The abundance of silica in the VRW sherds and therefore the proportion of inclusions, is the main difference separating samples classified in chemical groups 1 and 2.

The four sherds classified as chemical group 3

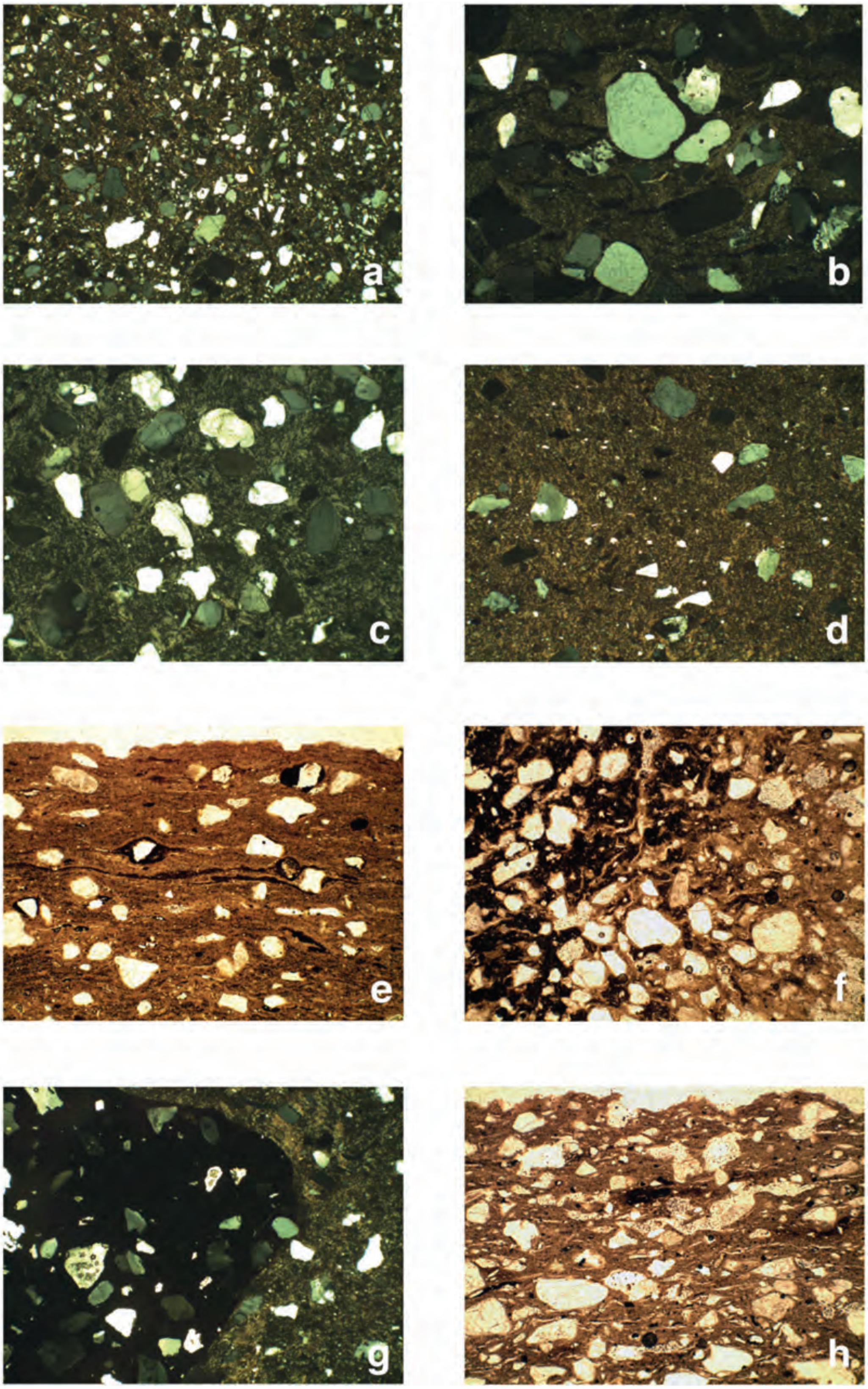

Fig 5. Thin section photomicrographs of selected VRW ceramics from Brockley Hill analysed in this study: a) BHC047 with abundant silt-sized inclusions; b) BHC031 with sparse medium sand-sized inclusions; c) BHC005 with light-coloured clay matrix; d) BHC017 with red-coloured clay matrix; e) BHC035 with distinctive red streaking in its clay matrix; f) BHC036 with dark mottling in its clay matrix; g) BHC020 with large iron rich nodule containing quartz clasts; h) BHC051 with elongate voids aligned parallel to the margin of the sherd. Images A–D and G taken in crossed polars and images E, F and H in plane polarised light. Image width = 2.9mm

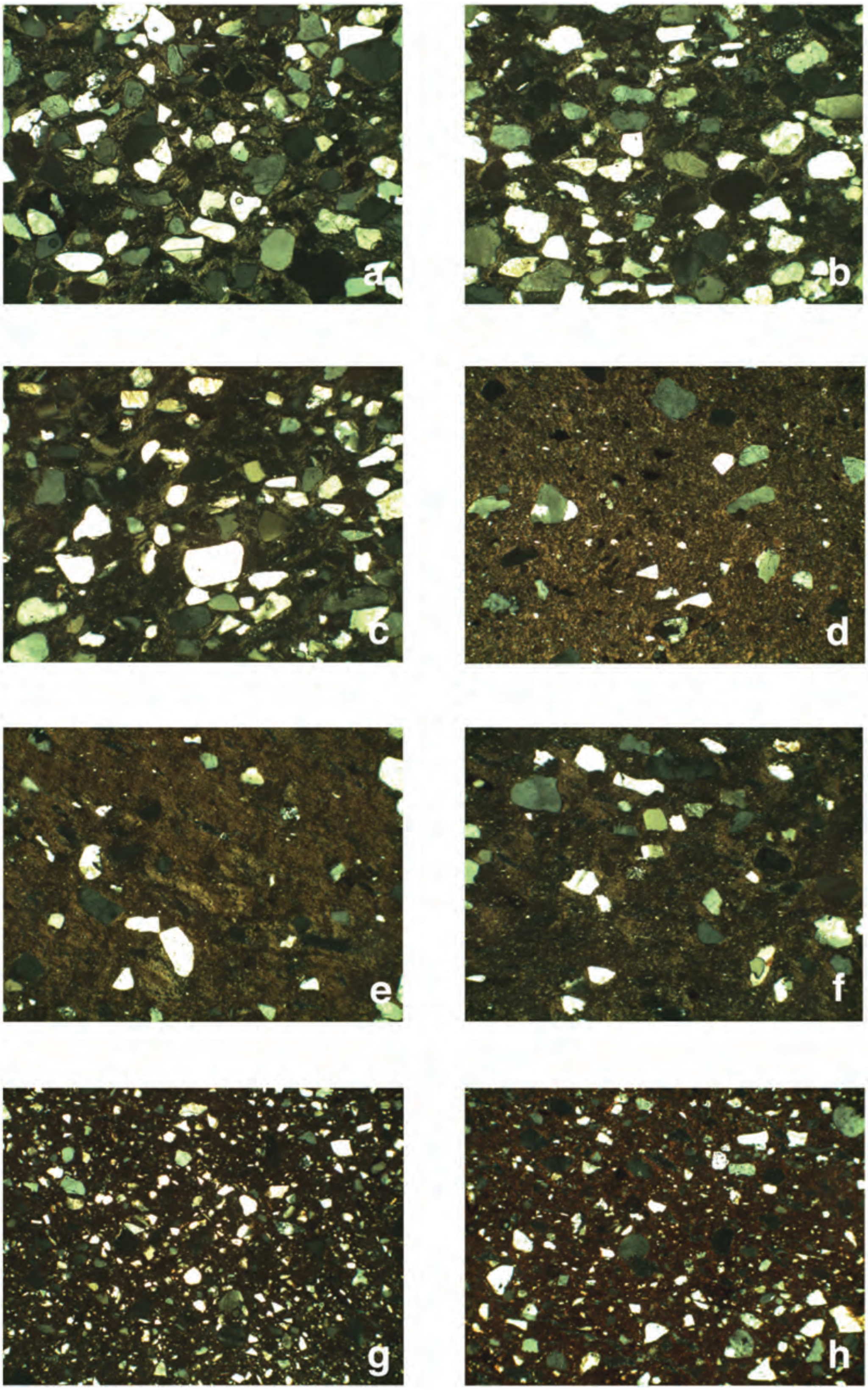

Fig 6. Thin section photomicrographs of selected VRW ceramics from Brockley Hill analysed in this study (a, d and g), alongside Brockley Hill (b and e) and Northgate House (c, f and h) VRW ceramics previously analysed by Tomber (2001) and Vince and Tomber (2005) illustrating close petrographic matches between the VRW ceramics of the two Roman kiln sites: a) BHC029; b) RTS562; c) RTS609; d) BHC017; e) RTS566; f) RTS610; g) BHC046; h) RTS533. All images taken in crossed polars. Image width = 2.9mm

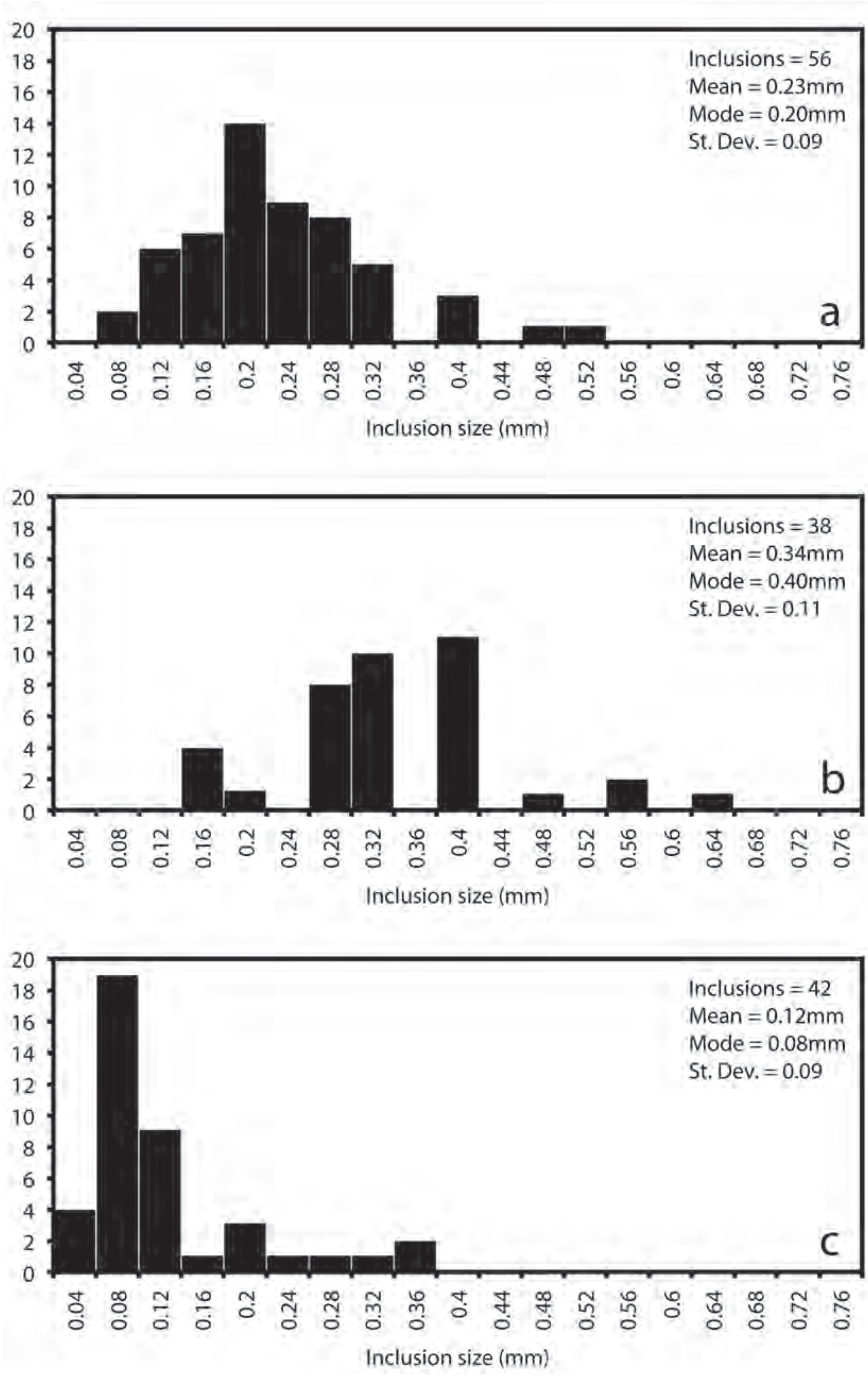

Fig 7. Grain-size distribution histograms of textural data from selected VRW ceramics analysed from Brockley Hill in this study. Data collected via point counting 100 points on each sample under the polarising light microscope (Table 2). Total number of inclusions counted, mean and mode inclusion size and standard deviation given for comparison: a) BHC029 (Fig 6a); b) BHC031 (Fig 5b); c) BHC047 (Fig 5a)

(BHC032, 033, 034 and 035) are defined by their greater abundance of Ce, Fe, La and Y compared to the other 46 analysed samples. This is visible in scatterplots of these elements (Fig 8f). The presence of red streaking in these sherds (Fig 5e), all of which originated from Phase 4, might suggest that intentional clay mixing is responsible for their unique chemical signature. Though it is worth noting that similar features also occur in other Brockley Hill VRW samples.

6. Comparison with Previous Analytical Studies

Petrographically, the 50 ceramic samples in this study are comparable to the five VRW thin sections from Brockley Hill analysed by Vince and Tomber (2005; see also Tomber 2001) and some close matches exist (Fig 6). These previously analysed samples are also characterised by quartz-rich sand temper in a light-coloured (Fig 6b) or more reddish (Fig 6e) clay matrix. As with the 50 samples analysed here, significant variation exists in terms of the size and abundance of the sand inclusions as well as the colour and texture of the matrix. Only two of the five samples have a light-firing clay matrix that is thought to be characteristic of VRW (Fig 6b). Ceramics with the more silty, red-firing composition detected in this study (Fig 4g), were not represented in Brockley Hill samples analysed by Vince and Tomber (2005). Mottling was present in the clay matrix of several samples and one contains some red clay-rich features. One sample contains probable grog temper that was not seen in the VRW samples analysed here.

The nine VRW thin sections analysed by Vince and Tomber (2005) from Northgate House also exhibit similar petrographic variation that overlaps with that of Brockley Hill and includes some good compositional matches (Fig 6). As at Brockley Hill, not all the VRW samples are characterised by a light-firing clay matrix. The reddish-firing silty composition detected in the 50 VRW ceramics in this study is present in these previously analysed VRW thin sections from Northgate House (Fig 6h). Grog temper is present in one sample, though this occurs in a compositionally different fabric from the Brockley Hill sample of Vince and Tomber (2005) mentioned above.

In their geochemical classification of 16 VRW samples from Brockley Hill and Northgate House, Vince and Tomber (2005; see also Vince 2002a; 2002b) revealed that the ceramics from both sites exhibit compositional variability. Unfortunately, it is not possible to classify statistically the elemental composition of the 50 sherds of VRW from Brockley Hill determined by ED-XRF in this study, alongside the ICP-MS data on the 16 contemporaneous ceramic samples obtained by Vince and Tomber (2005). However, by comparing the average abundance of specific elements in the two datasets (Table 5) it is possible to see that the VRW ceramics in this study have a close chemical composition to those analysed by Vince and Tomber (2005) from Brockley Hill and Northgate House. Comparisons between specific samples which are petrographically related in thin section (Fig 6) indicate that they also have similar elemental compositions for most major and minor elements (Table 5). Differences in the accuracy of the two geochemical datasets may be responsible for discrepancies in the abundances of certain trace elements.

Unfortunately, Devereux *et al* (1982) did not publish the elemental data from their XRF analysis of 92 VRW samples from Brockley Hill, Verulam Hills Field, Radlett and Little Munden, so it is not possible to compare this to the geochemical characterisation of Brockley Hill VRW in the present study.

7. Ceramic Raw Materials and Paste Preparation

The petrographic and geochemical variability within the 50 VRW sherds from Brockley Hill that has been revealed in this study (Figs 4, 5 and 8) may have several possible sources. Naturally occurring sedimentary deposits, exploited for ceramic production can contain significant variation in composition and texture (Hein *et al* 2004; Travé Allepuz *et al* 2014) and it is possible that some of the differences between the sherds can be ascribed to this. In addition, ceramic paste recipes are intrinsically variable and may be subject to fluctuations over time, especially if they are prepared by the admixture of several ingredients (Arnold *et al* 1991; Buxeda I Garrigós *et al* 2003). Given that the sherds analysed were produced over a *c* 100 year period it is possible that such an effect is also responsible for the compositional diversity of the analysed samples. Notwithstanding these influences certain clear compositional differences that are visible in thin section (Fig 5) and within the geochemical dataset (Fig 8) are likely to be due to the use of several raw materials sources for VRW production at Brockley Hill, as well as different methods of paste preparation. For example, ceramics characterised by rounded sand-sized inclusions and light-coloured clay matrix (Fig 5b) and those with a redder clay fraction and abundant silt sized-inclusions (Fig 5a) were clearly not produced using a single source of clay.

In order to identify the various types of raw materials used in the manufacture of VRW at Brockley Hill and identify their origins it is first necessary to consider the possible methods of paste preparation employed by potters at the site (Quinn 2013, 154–71). Certain analysed samples were almost certainly produced by the addition of sand-sized quartz-rich particulate temper to a fine light-firing clay source (Fig 5b and c), resulting a bimodal grain size distribution (Fig 7b). Vince and Tomber (2005) also speculated that sand temper could have been used for the production of VRW, pointing out

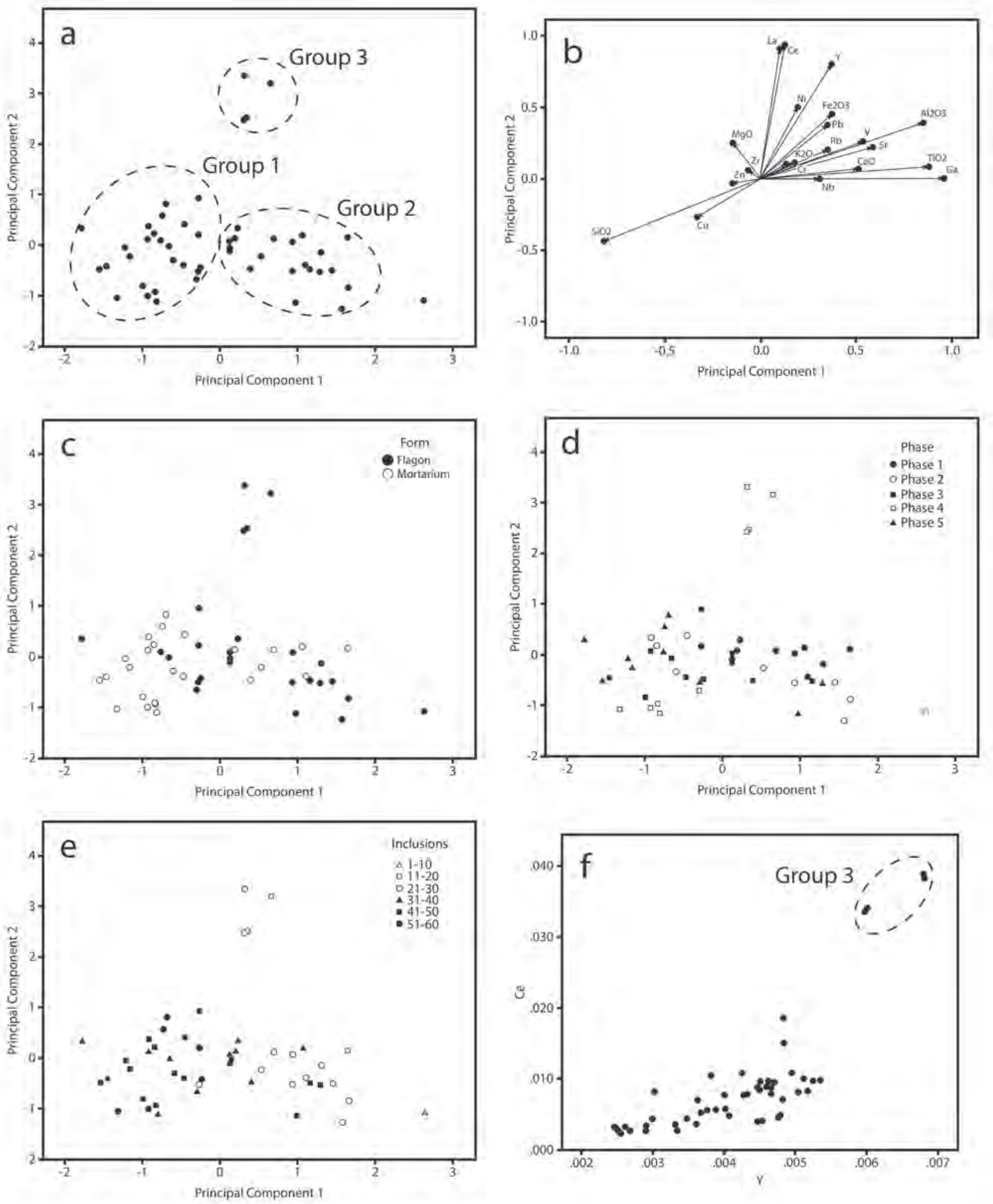

Fig 8. Results of the PCA classification the 50 VRW ceramic sherds from Brockley Hill analysed in this study, based on the normalised abundance of 23 major, minor and trace elements: a) Scatterplot of principal components 1 and 2 with chemical groups indicated; b) Factor plot of the influence of each of the 23 elements used in the PCA; c) Scatterplot of principal components 1 and 2 with vessel shape for comparison; d) Scatterplot of principal components 1 and 2 with site phase for comparison; e) Scatterplot of principal components 1 and 2 with abundance of inclusions (%) for comparison; f) Scatterplot of Ce against Y, with chemical group 3 indicated for plot of ceramics and clay samples

fine white-coloured London Eggshell Ware and London Marbled Ware from Northgate House is characterised in thin section by light-firing clay without sand inclusions.

The distinctive silty, micaceous, reddish VRW samples (Figs 5a and 6g) were not produced using the above clay paste recipe, due to their different clay matrix and the finer, unimodal nature of their inclusions (Fig 7c). It is likely that these ceramics were manufactured from a more iron-rich, silty clay source and without the addition of sand temper. A possible third recipe used for the manufacture of VRW at Brockley Hill is the mixture of a light and a darker coloured clay source in varying proportions with quartz-rich sand temper (Fig 5e). Such a scenario was proposed by Vince and Tomber (2005, 176) for the production of VRW at Northgate House and is suggested by the presence of distinctive streaks and swirls in the clay matrix of several samples (Fig 5e). Vince and Tomber (2005, 176) did not detect clay mixing in the five Brockley Hill VRW samples that they analysed, prompting them to infer that this red clay source could have had been collected locally to Northgate House.

In an attempt interpret the possible sources of the three ingredients that appear to have been the main raw material ingredients used at Brockley Hill for the production of VRW, we have compared them petrographically and geochemically with the nine field samples collected in the general area of the site (Fig 4; Table 3). Exact compositional matches between archaeological ceramics and geological field samples are generally rare (Quinn 2013, 134–5) due to the intentional processing and mixing of clay and temper during pottery manufacture. However, we hoped to determine more generally whether sources of fine light-firing clay, red silty clay and quartz-rich sand were available near Brockley Hill.

Vince and Tomber (2005, 175) suggest that workshops in the Verulamium region pottery industry including Brockley Hill exploited light-firing clay of the Reading Beds (Fig 4). A source of light-coloured clay was sampled from a disused brickworks near Radlett, *c* 4km north of Brockley Hill (Fig 4; Table 3). This belongs to the Cenozoic Lambeth Group which includes the Woolwich and Reading Beds (Sumbler 1996, 99). In thin section fired briquettes of this clay source had a red-coloured clay matrix and contained abundant fine quartz and glauconite. This seems to rule it out as the source of the fine light-firing clay source used for the production of some of the VRW at Brockley Hill.

A possible source of sand temper exists at the site of Brockley Hill itself. The high ground in this area is occupied by superficial sand and gravel deposits of the Quaternary Stanmore Gravel Formation. However, these poorly-lithified fluvial or shallow marine sediments are known to have a high proportion of chert clasts, as confirmed by the petrographic analysis of a field sample collected a Brockley Hill (Fig 4; Table 3). With this in mind, it is not clear whether the Stanmore Gravel deposits local to the kiln site were exploited for pottery production or whether another source of sandy material was used as temper. Suggett (1954) reported that a large quarry was found near the summit of Brockley Hill, which may have been located in the Stanmore Gravel Formation. Unfortunately, this could no longer be located.

The Stanmore Gravel lies on top of Cenozoic deposits of the Claygate Member of the London Clay Formation. This grey-coloured clay material was sampled in several locations near to the site (Fig 4; Table 3). In thin section it is characterised by red-firing clay with abundant sub-angular silt-sized quartz clasts and occasional white mica. These compositional characteristics might make it a candidate for the clay source used in the manufacture of the silty, reddish VRW ceramics from Brockley Hill (Figs 5a and 6g). Indeed, Tomber (2001, 1) puts forward this suggestion for the related VRW that she analysed from Brockley Hill. However, the field samples collected from the Claygate Member are considerably redder and more iron-rich than these sherds. They also contain rounded glauconite inclusions that are characteristic of the London Clay Formation, but do not appear to be present in the ceramics. London Clay, though widespread in southern Britain is not used at the present day for the mass production of ceramic products due to its high shrink-swell capacity (Sumbler 1996, 140). However, this could have been overcome by mixing it with another type of compositionally different clay.

Vince and Tomber (2005, 176) seem to suggest that the ‘red firing micaceous clay’ that they suspect was used in the production of some VRW at Northgate House could have been collected locally. However, their analysis of a highly heterogeneous sample of kiln lining from Brockley Hill reveals that one of its components is also a ‘red-firing clay with abundant quartz and muscovite silt’ (Vince and Tomber 2005, 175). This sample also contains sandy white material with rounded quartz sand of the type that may have been used for the manufacture of a significant number of other VRW sherds (eg Fig. 5b and c). Clay used for non-portable structures such as kilns or furnaces is often assumed to be locally derived. With this in mind it is possible that both a reddish silty clay source and light-firing clay were available at Brockley Hill, even though their exact locations could not be identified in this study.

Unfortunately, Vince and Tomber (2005) did not analyse any field samples of possible ceramic raw materials. Their interpretation of the transport of clay and/or pre-mixed paste from Brockley Hill to Northgate House appears to be based solely on the similarity between the VRW sherds excavated from the two sites. This and other alternative explanations for the close compositional relationship between the ceramic products of Brockley Hill and Northgate House are discussed below in the light of the new evidence provided by this study.

Our petrographic analysis of the 50 VRW sherds reveals that many of them contain elongate voids that are aligned parallel to the margins of the parent vessel. These voids, which are likely to have formed during drying, follow the preferred alignment of the clay minerals in the samples, suggesting a strong vertical force during the pottery forming process. This is consistent with manufacture on a fast potter's wheel (Woods 1982; Whitbread 1996).

The optical activity of the clay matrix of the VRW sherds under crossed polars (XP) suggests that the ceramics were fired at a relatively low temperature, below *c* 850°C (Reedy 2008, 186; Quinn 2013, 191). The uniform colour within the thin sections indicates oxidising conditions and a sufficiently long firing duration allowing oxygen to fully penetrate the walls of the vessels.

8. Discussion and Conclusions

The detailed petrographic and geochemical analysis of well-dated VRW mortaria and flagon sherds from across the known operational period of the important Verulamium region pottery industry kiln site of Brockley Hill near Stanmore in Middlesex, has revealed that a high degree of compositional diversity exists within this common Romano-British ceramic ware. This echoes and amplifies the previous findings of Devereux *et al* (1982) and Vince and Tomber (2005) on selected samples from Brockley Hill and other Verulamium region pottery industry sites, as well Northgate House in the Upper Walbrook valley, London. The findings of the present study, which are based on the analysis of a large assemblage of 50 sherds clearly demonstrate the use of several different clay paste recipes and raw material sources at Brockley Hill. These include fine light-firing clay and quartz-rich sand temper, fine silty, micaceous more red-firing clay without added temper, and perhaps a mixture of the two. Comparisons with the local geology and selected field samples have provided clues as to the possible origins of some of these clay and temper sources, while the locations of others is unclear. The existence of gradational variation between the 50 samples that is difficult to subdivide visually and quantitatively seems to suggest the presence of natural geological variability that could be related to the use of these raw material sources over a long time, as well as the intentional or accidental mixing of the components in different amounts.

Notwithstanding some minor patterns such as the presence of less inclusion-rich flagons in Phase 2 (Flavian period) more inclusion-rich mortaria in Phase 5 (early Antonine period), very few clear correlations exist between either the shape of the pottery or the phase of the site from which the sherds originated. This appears to rule out the possibility that specific raw materials or recipes were used for the manufacture of VRW pottery with particular functions, or that there were distinct, conscious changes in raw materials and/or technology at the site over time. However, the existence of several recipes that occur in contexts from several operational phases of the site is interesting and requires further explanation.

Given the discovery at Brockley Hill of VRW mortaria stamped with 32 different dies (Castle 1976, 211), it is perhaps tempting to interpret these paste recipes as the activities of several different potters working at the site. However, it has been proposed that the names depicted on Roman pottery stamps might in fact be those of potters acting as managerial persons or *officinatores* (Fülle 1997, 144) which could have been in control of different kilns. This could explain the presence at distant kiln sites of pottery stamped with the same die, without the need to invoke the itinerant movement of potters themselves (*cf* Hartley 2012, 113–14). It also offers an interesting perspective from which to understand the possible links between VRW production at Brockley Hill and Northgate House.

Our re-examination of the thin sections and geochemical data of Tomber (2001), Vince (2002a; 2002b), and Vince and Tomber (2005) indicate that their 16 samples have a very close petrographic and chemical composition to the 50 Brockley Hill sherds analysed in this study. Both datasets contain a similar range of petrographic and elemental variability and exhibit some very good petrographic and geochemical matches (Fig 6). The similarities between the Brockley Hill VRW samples analysed by Vince and Tomber (2005) and the material in this study is perhaps not surprising. However, the close compositional relationship between Brockley Hill and the Northgate House VRW ceramics of these authors is very interesting. Vince and Tomber (2005, 175) noted the similarity between the VRW of these two sites, but claimed that some of the Northgate House ceramics differed in that they were produced by the addition of 'local red-firing clay'. Our comparisons with their thin sections indicates that VRW pottery with this composition is in fact also present at Brockley Hill. Petrographic re-examination also revealed the presence of rare fired pottery inclusions within certain samples from both sites, which could represent the addition of grog temper.

Quantitative textural data has been used in some cases to define the products of different kiln sites and distinguish between them in exported material (Streeten 1982; Middleton *et al* 1985). The grain-size analysis of VRW ceramics from Northgate House might be a possible line of enquiry for future attempts to characterise its VRW and detect differences between this and Brockley Hill. However, the range of textural variation that has already been revealed by the study of Vince and Tomber (2005) suggests that this could prove difficult.

The striking compositional match between the range of VRW compositions within material excavated at Brockley Hill and Northgate House means that few clear criteria currently exist with which to characterise the macroscopically similar pottery of these two separate kiln sites and it may therefore be difficult to distinguish between their products at other Roman sites in Britain. This unfortunate conclusion raises several important questions about VRW pottery and its production at Brockley Hill and Northgate House. Firstly, the data clearly indicate that pottery that is classified macroscopically as VRW contains a range of compositions, even at quite distant sites. That the supposed macroscopic similarity within VRW is not matched by compositional homogeneity perhaps suggests that this ware group should be re-assessed. Verulamium Region White Ware has long been known to exist in a range of colours (Tyers 1996, 199; Tomber and Dore 1998, 154). However, the existence of compositions that deviate from the general fabric description of VRW, such as the finer, redder, more silty and micaceous sherds detected at Brockley Hill and in the material of Vince and Tomber (2005) in this study, is not covered by the current definition of the ware.

The close petrographic and geochemical similarity between VRW from Brockley Hill and Northgate House might be interpreted in several ways. Since outcrops of light-firing clay do not occur in the area of Northgate House, that is characterized by the London Clay formation, Vince and Tomber (2005, 176) see it as evidence for the import of clay from Brockley Hill to Northgate House, perhaps with pre-mixed sand temper, where it was used to manufacture similar pottery. Whilst examples of the transport of ceramic raw materials in Roman times over distances of up to 10 km exist (eg Young 1977, 16), the kiln sites Brockley Hill and Northgate House are *c* 20 km apart. Transporting large quantities of clay and temper between these two locations would have been a significant undertaking in Roman times, despite the existence of Watling Street connecting the two (Fig 1).

If raw materials were indeed transported from Brockley Hill to Northgate House in order to produce VRW some 20 km closer to Roman London, then this perhaps implies that the local demand for this pottery must have been high. The possible movement of clay between the two sites also suggests that they were closely connected to one another. The presence of some VRW mortaria stamped with the same dies at Brockley Hill and Northgate House (Hartley 2005, 84) may indicate that certain *officinatores* were associated with the production of this class of pottery in both production centres. These workshop managers could have supplied raw materials to several different ‘branches’ and overseen the manufacture of VRW using specific preferred recipes.

The presence of multiple kiln structures at Brockley Hill might be in keeping with a model of multiple zoned workshop units (*officinae*) arranged in larger organisational units (*fliglinae*) (Seeley and Thorogood 1994). According to written sources from elsewhere in the Roman Empire (eg Fülle 1997, 121), lease contracts or a *locatio conductio* existed between *officinatores* and the owner the land or of a large pottery production centre, who was usually a person of a higher social status. If the Verulamium region pottery industry was set up in order to meet the demands of the Roman garrisons flooding into Britain, then it is possible that Brockley Hill and other Verulamium region kiln sites could have followed such a model, with the landowner establishing the facility and offering contracts to suitable potters acting as workshop managers to produce a restricted repertoire of pottery vessels for a specific market.

The kiln site of Northgate House, which appears to have been in operation for a shorter period, during the second century AD, might represent a new production centre set up by the same or a different landowner in which *officinatores* from Brockley Hill and other sites also operated, bringing their raw materials and recipes with them. This tentative hypothesis might explain the close compositional similarity between VRW from Brockley Hill and Northgate House revealed by Vince and Tomber (2005) and this study. Its feasibility could be further tested through the detailed study of pottery stamps at the two sites as well as the compositional analysis of ceramics from other production centres in the Verulamium region pottery industry.

An alternative explanation to that above, and one which should certainly be considered, is that Northgate House contains VRW sherds that were produced in Brockley Hill and that could have been used as examples for copying. If the transport of raw materials over 20km is deemed to be unlikely, then the close compositional matches between the ceramics of the two sites could be explained in this way. This would imply either the consumption or discard of VRW produced at Brockley Hill by potters working at Northgate House. Such a possibility might be further explored by a re-examination of the available evidence for VRW production at both sites.

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Table 4. Normalised geochemical data for the 50 VRW ceramic sherds analysed from Brockley Hill in this study, as determined by ED-XRF. Major and minor elements expressed as weight percent (wt %), and trace elements expressed as parts per million (ppm). Elements below limits of detection and those potentially affected by alteration or contamination have been omitted. (F: flagon; M: mortarium)

Sample	Shape	Phase	Chemical Group	Major and minor elements - Weight percent (wt %)								Trace elements - Parts per million (ppm)														
				MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	V	Cr	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	La	Ce	Pb
BH09	F	1	1	0.33	19.65	76.62	0.27	0.32	1.02	0.01	1.37	75	242	25	18	28	20	8	32	48	177	19	73	37	71	12
BH11	M	3	1	0.43	19.01	76.13	0.54	0.37	0.76	0.01	2.17	61	239	24	41	35	19	21	44	33	167	13	141	32	28	21
BH12	M	3	1	0.55	15.97	77.42	1.23	0.40	0.74	0.01	2.97	106	138	29	35	47	15	44	46	36	304	19	195	28	36	22
BH13	M	3	1	0.54	20.68	74.72	0.70	0.30	0.61	0.01	2.10	70	301	46	53	38	15	30	39	27	146	15	114	30	27	17
BH15	M	3	1	0.71	15.71	78.28	0.86	0.36	0.73	0.02	2.86	99	225	27	108	32	19	26	39	29	175	16	155	22	27	15
BH21	M	2	1	0.57	19.45	75.53	0.28	0.32	0.92	0.01	1.44	74	263	28	19	22	17	9	34	45	248	57	66	34	88	15
BH22	M	2	1	0.26	19.21	77.08	0.26	0.29	0.94	0.02	1.48	65	295	31	32	25	19	10	34	45	268	66	65	24	85	17
BH23	M	2	1	0.39	19.36	76.05	0.47	0.28	0.77	0.01	2.11	56	239	23	22	49	18	15	39	30	153	15	134	36	44	18
BH24	M	2	1	0.31	19.09	76.96	0.30	0.32	0.92	0.02	1.58	87	267	21	53	22	19	9	34	50	161	19	85	47	109	13
BH26	M	4	1	0.47	15.78	80.25	0.54	0.36	0.71	0.01	1.53	78	263	18	32	21	17	20	41	25	161	12	124	22	24	16
BH27	M	4	1	1.16	16.79	77.23	1.36	0.08	0.71	0.02	1.58	78	226	18	68	43	18	24	20	26	144	14	102	28	32	15
BH28	M	4	1	0.55	16.57	79.24	0.87	0.17	0.72	0.01	1.53	117	242	18	27	58	20	23	29	25	151	14	113	24	31	15
BH29	M	4	1	0.51	17.54	78.30	0.85	0.21	0.73	0.01	1.49	59	237	18	34	71	19	15	30	25	153	16	107	28	32	14
BH30	M	4	1	0.48	17.41	78.36	0.62	0.32	0.72	0.01	1.70	82	211	18	44	62	18	18	37	25	153	13	120	29	27	16
BH31	F	4	1	1.04	18.32	74.52	1.74	0.46	0.79	0.01	2.79	124	267	31	20	81	20	75	62	30	156	16	208	48	82	24
BH38	F	3	1	0.66	19.36	75.42	0.76	0.26	0.76	0.01	2.36	109	261	32	32	53	20	38	42	40	202	18	158	36	58	23
BH39	F	3	1	0.46	18.20	76.01	0.45	0.33	0.83	0.01	3.09	96	238	27	45	27	22	19	37	33	179	20	211	23	35	18
BH40	F	3	1	0.60	20.68	73.35	0.63	0.41	0.96	0.01	2.99	122	256	25	33	49	19	31	48	48	212	21	164	71	186	27
BH43	M	5	1	0.91	19.79	73.35	1.70	0.33	0.84	0.01	2.53	146	270	35	32	54	18	72	60	48	259	17	254	71	150	28
BH44	M	5	1	0.94	17.52	76.04	0.96	0.27	0.60	0.01	2.07	54	249	23	30	37	13	37	50	29	249	16	203	30	34	22
BH45	M	5	1	0.63	18.11	72.82	0.73	0.58	0.95	0.19	4.24	110	172	44	31	104	19	29	109	52	313	18	377	51	97	30
BH46	M	5	1	0.88	18.14	73.89	1.93	0.28	0.93	0.02	3.32	139	227	32	20	48	18	68	56	47	425	22	265	57	80	20
BH47	M	5	1	1.18	17.35	75.09	1.55	0.24	0.85	0.01	2.26	133	271	25	25	35	19	65	61	42	354	22	243	51	108	24
BH48	F	5	1	0.61	19.36	74.83	0.96	0.36	0.86	0.02	2.32	89	268	24	22	42	20	43	56	37	255	18	234	29	52	46
BH50	F	5	1	1.01	16.13	76.48	1.98	0.33	0.80	0.01	2.76	97	292	39	20	82	15	77	56	51	329	16	268	52	100	35
BH52	F	5	1	0.84	18.30	75.05	1.30	0.24	0.96	0.01	2.80	80	220	27	29	45	21	53	66	45	292	22	230	55	96	45
			Mean	0.65	18.21	76.12	0.92	0.32	0.81	0.02	2.29	93	245	27	35	47	18	34	46	37	222	21	170	38	67	22
			Standard Deviation	0.26	1.46	1.86	0.53	0.09	0.11	0.04	0.72	27	36	8	19	21	2	22	17	10	77	13	77	15	42	9
BH01	M	1	2	0.54	23.88	71.15	0.72	0.30	1.04	0.01	1.71	90	270	28	35	29	25	28	48	50	155	23	116	41	82	18
BH02	M	1	2	0.69	24.21	69.65	1.32	0.27	1.07	0.01	2.44	128	261	30	16	28	26	59	62	43	167	21	163	34	79	21
BH03	M	1	2	0.41	19.74	74.86	0.45	0.30	1.05	0.01	2.74	111	260	27	34	32	22	17	38	43	196	22	100	30	77	75
BH04	M	1	2	0.66	28.22	65.96	1.14	0.36	1.15	0.01	2.10	102	264	32	14	39	30	50	68	54	191	27	174	47	98	27
BH05	M	1	2	0.58	24.92	69.96	0.60	0.31	1.13	0.01	1.83	92	297	31	20	29	28	23	49	52	171	25	124	38	83	17
BH06	F	1	2	0.69	25.19	68.42	1.19	0.28	1.09	0.01	2.70	88	267	33	14	41	26	55	62	46	187	24	190	48	89	24

BH07	F	1	2	0.64	23.91	65.37	1.71	0.39	1.12	0.01	5.19	101	179	33	23	60	27	75	116	46	217	28	460	43	97	29
BH08	F	1	2	0.58	20.65	74.35	0.76	0.29	1.03	0.01	1.97	129	254	27	29	33	23	32	44	45	189	23	117	43	85	18
BH10	F	1	2	0.78	20.88	71.93	0.68	0.31	1.03	0.01	2.66	115	278	36	23	27	24	28	46	47	188	21	113	41	88	19
BH14	M	3	2	0.59	21.36	72.96	1.23	0.36	1.00	0.01	2.01	104	303	26	15	35	21	52	61	39	201	21	202	43	57	31
BH16	F	2	2	0.58	22.40	70.64	0.95	0.40	1.24	0.01	3.11	165	261	33	35	37	32	51	62	48	241	26	262	39	48	30
BH18	F	2	2	0.86	22.44	69.59	1.00	0.40	1.21	0.02	3.24	131	229	32	29	33	27	54	55	45	245	31	197	26	41	28
BH19	F	2	2	0.69	23.25	69.58	1.78	0.41	1.19	0.01	2.66	146	336	23	15	31	29	87	82	38	263	41	267	40	56	39
BH20	F	2	2	0.41	22.67	69.33	1.11	0.50	1.32	0.01	3.01	173	214	34	35	43	32	56	99	48	320	52	396	27	46	36
BH25	M	2	2	0.78	22.20	70.78	0.97	0.26	0.98	0.01	2.47	115	288	27	20	35	24	45	53	40	180	18	166	44	77	26
BH36	F	3	2	0.77	22.38	71.01	1.19	0.34	1.00	0.01	2.86	115	283	35	48	54	24	55	54	47	269	20	186	46	96	28
BH37	F	3	2	0.68	24.20	69.32	1.11	0.36	1.20	0.01	2.68	118	280	23	32	43	27	48	52	38	224	22	193	50	105	31
BH49	F	5	2	0.55	23.03	68.76	0.51	0.71	1.01	0.02	3.35	175	208	28	30	70	25	16	108	41	245	23	206	26	48	29
BH51	F	5	2	0.87	19.51	72.40	1.49	0.33	1.30	0.03	3.47	177	342	23	22	44	25	61	56	35	268	22	256	32	44	71
			Mean	0.65	22.90	70.32	1.05	0.36	1.11	0.01	2.75	125	267	29	26	39	26	47	64	44	217	26	205	39	74	32
			Standard Deviation	0.13	2.07	2.42	0.38	0.10	0.11	0.01	0.78	29	40	4	9	11	3	19	22	5	43	8	94	8	21	16
BH32	F	4	3	0.93	25.59	65.81	1.37	0.41	1.03	0.02	4.35	106	281	35	16	43	25	65	78	68	221	22	214	161	389	54
BH33	F	4	3	1.08	23.40	66.85	1.60	0.40	1.00	0.01	4.00	164	287	35	23	40	25	73	80	60	222	22	246	144	340	55
BH34	F	4	3	0.82	23.87	68.39	1.37	0.37	0.98	0.01	3.71	184	282	33	15	39	22	64	74	60	210	18	221	132	336	48
BH35	F	4	3	0.84	26.11	65.33	1.37	0.39	1.07	0.01	4.34	198	237	37	18	42	25	64	75	68	219	23	212	151	383	53
			Mean	0.92	24.74	66.59	1.43	0.39	1.02	0.01	4.10	163	272	35	18	41	24	67	77	64	218	21	223	147	362	52
			Standard Deviation	0.12	1.31	1.35	0.12	0.02	0.04	0.00	0.31	40	23	2	4	2	1	5	2	5	6	2	16	12	28	3
BH17	F	2	Outlier	0.50	25.63	65.62	1.43	0.77	1.34	0.01	3.47	154	230	34	26	53	34	72	104	45	269	30	461	29	40	36

Table 5. Comparison between the geochemical compositions of VRW ceramics analysed in this study with data on 16 VRW sherds analysed by Vince (2002a; 2002b) and Vince and Tomber (2005) from Brockley Hill and Northgate House. The upper part of the table compares the mean and standard deviation of selected elements. The lower part of the table compares the geochemistry of specific samples from the two datasets that have a related petrographic composition in thin section (Fig 4). Certain elements have been left out due to their absence in one of the datasets. Data normalised to 100%.

		MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3	V	Cr	Ni	Cu	Zn	Sr	Y	Zr	La	Ce	Pb
Brockley Hill This study n = 50	Mean	1	21	73	1	0	1	3	112	255	29	30	43	57	42	221	47	92	28
	Standard Deviation	0	3	4	0	0	0	1	36	38	6	16	17	22	11	62	32	87	14
Brockley Hill Vince and Tomber 2005 n = 11	Mean	0.72	18	76	1	0.29	0.70	2.8	94	100	29	16	59	62	24	70	68	132	44
	Standard Deviation	0.23	2.9	4.2	0.42	0.072	0.11	0.76	27	16	7.0	6.6	29	17	12	13	43	102	15
Northgate House Vince and Tomber 2005 n = 5	Mean	1	19	76	0.85	0	0.65	3.1	87	86	28	15	34	66	27	73	62	120	31
	Standard Deviation	0.23	2	3.5	0.55	0.38	0.23	0.81	28	15	13	5.7	12	24	8.8	12	17	35	13
	Sample	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3	V	Cr	Ni	Cu	Zn	Sr	Y	Zr	La	Ce	Pb
Brockley Hill This study	BHC029 Fig 6 A	0.51	17.54	78.3	0.85	0.21	0.73	1.49	59	237	18	34	71	30	25	153	28	32	14
Brockley Hill Vince and Tomber 2005	RTS562 Fig 6 B	0.35	13.54	83.2	0.72	0.1	0.56	1.47	51	82	17	9	31	27	9	57	26	34	31
Northgate House Vince and Tomber 2005	RTS609 Fig 6 C	0.32	16.72	79.9	0.27	0.16	0.45	2.16	55	67	17	10	21	44	18	57	42	82	19
Brockley Hill This study	BHC017 Fig 5 D	0.50	25.63	65.6	1.43	0.77	1.34	3.47	154	230	34	26	53	104	45	269	29	40	36
Brockley Hill Vince and Tomber 2005	RTS566 Fig 6 E	0.73	21.26	72	1.31	0.33	0.81	3.44	108	114	29	12	40	80	42	95	141	320	60
Northgate House Vince and Tomber 2005	RTS610 Fig 6 F	0.87	21.73	70.8	1.54	0.56	1.02	3.25	116	86	32	24	42	72	23	86	52	101	17
Brockley Hill This study	BHC046 Fig 6 G	0.88	18.14	73.9	1.93	0.28	0.93	3.32	139	227	32	20	48	56	47	425	57	80	20
Northgate House Vince and Tomber 2005	RTS533 Fig 6 H	0.79	13.11	79.6	1.36	0.4	0.66	3.89	104	84	28	20	48	56	16	68	31	48	33