MIDLANDS PURPLE AND CISTERCIAN-TYPE WARES IN THE WEST MIDLANDS IN THE 15TH–16TH CENTURIES

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Midlands purple and Cistercian-type wares in the west Midlands in the 15th–16th centuries

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Project summary

Midlands purple and Cistercian-type wares are some of the commonest wares on late medieval–post-medieval sites in the west Midlands and are known to have been produced at several centres across the historic counties of Derbyshire, Staffordshire and Warwickshire, and possibly Shropshire. It was recognised, however, that the products of different early production centres (specifically here Ticknall, south Derbys; Burslem, Staffs; Wednesbury, Staffs now West Midlands; Nuneaton, Warks) could not be differentiated at consumer sites in the region; this considerably hampers study of both the industry's origins and dating, and of the production and distribution of these wares across the whole region. Scientific investigation (inductively-coupled plasma spectroscopy and petrography) of samples from all the known major early production centres is used here to try to achieve greater characterisation of these wares in terms of fabric-type and, thereby, their attribution to specific sources. The intention of this pilot study was to test how far the results of the scientific work could be translated into the definition of fabrics that could be visually determined, either in hand specimen or, more likely, with x20 microscopy.

The ICPS work was highly successful in identifying separate sample groups, based on the clay chemistry, and thus 'fabric-types' for each production centre and in some cases for different production sites within a centre. Not all fabrics were chemically sufficiently different, however, for the full differentiation of all production centres when applied to the identification of pottery from two consumer sites with stratified early material (Austin Friars Leicester and Bordesley Abbey, Worcs). This limited test case was successful in suggesting provenance for traded ceramics, particularly for the Cistercian-type vessels, in the period prior to the Dissolution, and the ICPS analysis indeed led to the recognition of another source for Midlands purple ware that cannot presently be identified. Conversely, negative evidence from the test case for Nuneaton products highlighted that distributions may not be readily predictable based simply on distance, and that provenance should not be presumed based on proximity.

The individual chemical fabric groups thus created could be compared with the petrographic and macroscopic (visual) data. Petrographic study confirmed the relative limitations of the thin-section technique for these highly fired ceramics, both coarse (Midlands purple) and fine (Cistercian-type) wares.

Guidance is provided on fabric recognition, though in the majority of cases it proved impossible to visually distinguish with certainty fabrics from particular production centres within the selected consumer site assemblages, except in the case of some of the Wednesbury Cistercian-type ware. Within the parameters of the project the nature of the uncertainties are discussed, and the greater publication of forms (including decoration) is urged as an important way to further the study of this material. Further scientific work is also encouraged given that the interpretation of fresh data will be facilitated by the substantial dataset reported here.

While the results of this preliminary study are not entirely clear-cut, this review of what is a major ceramics industry has achieved its aim of providing guidance for future research and management. Reference material relating to the results of the project is being made available at the Worcestershire Historic Environment and Archaeology Service, and the report will be made available on the Web in support.

1. Introduction

During the later medieval and earliest post-medieval periods very similar Midlands purple and Cistercian-type wares (sometimes also referred to as late medieval/transitional wares) were made across the Midlands from the late 15th and into the 16th century (for a recent summary see eg Boothroyd and Courtney 2004, 94–6). There were several relevant ceramic production centres, with the main ones at Wednesbury and Burslem (both historically in Staffs, but the former now in West Midlands; historic counties are used throughout below), Nuneaton (Warks), and Ticknall (Derbys) (Fig 1). However, the attribution of archaeological material to specific production areas has been problematic due to the visual similarities of these wares, despite their diverse production. This project aims to establish a base-line characterisation of these wares in terms of fabrics based on scientific analyses, and to use these data to support the identification of material from two consumer sites as a test case with a view to establishing a better understanding, and possibly definition, of fabrics to assist in future management and research.

Realisation of the problems presented by these wares, together with an awareness that recent excavations at a number of west Midlands production sites have produced reasonably discrete and sizeable deposits of wasters, meant that this was a good time to finally engage with the in-depth investigation of these wares. Therefore, recently excavated material from Stoke (Burslem Market Place and Burslem School of Art, Staffs), Ticknall (Derbys) and Wednesbury (Staffs), and less recently at Chilvers Coton, Nuneaton (Warks), were all selected for inclusion in this scientific investigation. This material, alongside that from the two excavated monastic consumer sites (Bordesley Abbey and Austin Friars Leicester; Fig 1) where well-stratified and well-dated finds were also available, form the focus for this study.

The project was developed in consultation with English Heritage throughout 2008 (revised PD 20 Nov 2008; MP&Cist ware PD 03.doc), and the project work was undertaken from May 2009 to October 2010. The project was grant-aided by English Heritage and the Royal Archaeological Institute.

2. Background

Midlands purple and Cistercian-type wares

Midlands purple and Cistercian-type wares are typical finds on sites in the west Midlands in the later 15th to 16th centuries, and represent a high proportion of the ceramic finds from archaeological sites of this period.

In the case of the Midlands purple it is the method of manufacture (specifically a relatively high temperature firing) that is the defining characteristic of that ware and not the forms; the forms occur in other regions in other wares, for instance in East Anglia in Harlow (Essex) products (Davey and Walker 2009) or in the South-West, for instance Donyatt wares (Somerset; Coleman-Smith 1988). Even in the west Midlands wares the same forms continued to be made in standard earthenware, for instance the Hanley ware from Worcestershire (Bryant 2004). Midlands purple wares are, therefore, a regional tradition that contrasted with the surrounding regions and were specifically associated with the north-west Midlands in the later 15th to 16th centuries in the lead-up to the Industrial Revolution.

Cistercian-type wares have a different history and distribution in that they have been regarded as a type typical of the north of England (especially Yorkshire), where they have been well defined, and where a form typology for black multi-handled drinking vessels, often with applied white clay decoration, has been established (Brears 1971). In the Midlands this tradition apparently also took root, giving rise to dark-coloured drinking vessels which shared the same general characteristics, though in this area such pots are more often not black. These were in contemporary use with Midlands purple, and it is clear their production was usually in the same places. Black wares are a different tradition, often in a similar range of forms in the Midlands to Cistercian-type and Midlands purple wares, and, therefore, quite easily confused with the chronologically earlier wares in case of Cistercian-type wares. Black wares took hold in the later 16th century in London (www.museumoflondon/ceramics as cited in Davey and Walker 2009) and similar dates probably apply elsewhere. At the moment there is no reason to see Midlands-produced black-glazed wares as a development arising from the Cistercian-type ware of this region, though it is clear that in some cases the same production centres were involved.

Apart from the difficulty in defining the products of the various production centres, the chronology of these industries is also unclear, especially a convincing date for the inception of the industry. For instance, the earliest reliable documentary evidence for the Ticknall potteries is seven potters in 1538 x 1547 who may reasonably be presumed to be making purple and Cistercian-type wares (Spavold and Brown 2005, 16). However, potters are documented at Wednesbury from 1422 and at Burslem in 1448 (Boothroyd and Courtney 2004, 94, 79), and this may represent earlier production of the wares under study here. Likewise, despite the ubiquity of these wares on Midlands 'consumer sites' in the 16th/17th centuries, there is very little clear archaeological evidence for their occurrence in the first half of the 16th century and before, mainly because of a lack of well-stratified material from urban contexts where tight and independent dating is available. In this situation the ceramics from monastic sites are potentially quite the most crucial, as the Dissolution (theoretically) offers a valuable dating horizon for the purpose of elucidating the dating of these wares. In practice, however, it has turned out that the material published to date is very limited and/or poorly stratified (eg Hulton Abbey, Staffs; Sandwell Priory, historically Staffs, now West Midlands). Thus, in practice, pre-Dissolution and Dissolution-dated material from suitable consumer sites has been in short supply, which has exacerbated the problems associated with studying this material, and especially relating it back to specific production sites. Therefore the wider accumulation of archaeological data has so far failed to allow the sequence of ceramic development, based on fabric and form criteria, to be unravelled in detail, as in the normal course of archaeological endeavour, at points of consumption. This to some extent has become a vicious circle, where a fundamental inability to interpret deposits because of difficulties with ceramic dating etc then becomes the main reason for giving them less attention the next time material is available.

However, the principal issue remains that the Midlands purple and Cistercian-type ware products of different centres can not currently be distinguished from each other, and this presents a significant and continuing problem for the wider archaeology in the region, as basic trading distributions cannot be established which routinely serve to provide clues to the economic framework of any given place (trade hinterland and social connections etc). Although historical research has in the case of Ticknall gone a good way to rectifying this deficiency (Spavold and Brown 2005), in the case of the other production centres such good evidence is not so available.

The problems these wares present to the practice of archaeology in the region have indeed been acknowledged for some years and these wares have been the focus for a specialist meeting of the regional Medieval Pottery Research Group (MPRG), specifically on Cistercian-type and Midlands purple wares from Ticknall (Derbys) on 27 October 2007, when the current state of knowledge about this major industry as a whole was also reviewed.

2.1 Geology

No detailed geological context for the production sites has been included below; the emphasis of this project is on applying various characterisation techniques, including scientific analysis to identify and distinguish these wares, and on determining whether further progress can be made in visual definition through the designation of reference material, and not on examining the clay sources themselves. The following, therefore, is a generalised account of the geology for each production centre.

Wednesbury (after Eastwood *et al* 1925, and Whitehead and Eastwood 1927) – Carboniferous Middle Coal Measures are present comprising grey shales, clays/fireclays, sandstones, ironstones and coal (BGS solid sheet 168). Glacial clays, sand and gravels are also present on the surface.

Burslem (after Rees and Wilson 1998) – in common with the other towns making up Stoke-on-Trent Burslem is located on the Upper Coal Measures where both clay and coal are available, the former including Etruria Marl (variegated clays).

Nuneaton – the geology of this area is complicated and many geological periods are represented (Cook 1984), but the clays are likely to be primarily derived from Carboniferous deposits. Middle Coal Measures are present (Eastwood *et al* 1923).

Ticknall (after Carney *et al* 2002) – the village of Ticknall is situated on Carboniferous limestone, and presently the source of local potting clays is unclear. A deposit known as the Pottery Clay Formation in the higher part of the Middle and Upper Coal Measures is located only as close as 5km to the south-east and south-west. The Lower Coal Measures are located just to the south of Ticknall but whether they contributed raw materials to the potting industry is presently unknown.

3. Aims

3.1 Primary driver, activity type and programme

This project aims primarily to meet EH Corporate Aim and Objective Aim 1: Help people develop their understanding of the historic environment, 1A: Ensure that our research addresses the most important and urgent needs of the historic environment. (Reference: EH 2005, Making the Past Part of our Future; EH 2008, SHAPE 2008)

The primary Activity Type and Programme of this project is Research A1:

> What's out there?; defining, characterising and analysing the historic environment;
>
> Understanding artefacts and material culture (Sub-programme no. 11111.510).

This project aims to develop understanding of a major, transitional, ceramics industry whose products are some of the commonest wares on late medieval–post-medieval sites but an industry whose origins, dating and distribution are not sufficiently well understood. It is intended to achieve this by characterising the products of the main centres of early production; and by comparing with similar characterisation data for traded ceramics from two key early consumer sites.

It is the first study of this west Midlands industry on a region-wide basis. Using a range of fabric characterisation techniques, it aims to create a knowledge base for future work and provide commercial and research organisations with the information they need to ensure efficient use of resources.

3.2 Supporting national, regional and thematic research frameworks

This project responds to acknowledged research priorities:

a) to national research priorities as summarised in the English Heritage research agenda (2005; especially Themes A and G), and detailed in English Heritage implementation plan for *Exploring our past* (1998), where eg Primary Goal A identified the need for accessibility of information, targeted additional data collection and synthesis, and to encourage and maximise collaboration between institutions;

b) to the national research priority 'The meaning of change (transitions), Processes of change, PC7 Transition from medieval to post-medieval traditions (c 1300–1700 AD)'

(English Heritage research agenda 2005, 45), and in particular to the national thematic research agenda outlined in the review *Medieval ceramic studies in England* (EH 1994) which highlighted the need for studies to examine periods of ceramic transition and noted specifically that the longevity of late medieval wares and vessel forms requires further study in many areas;

c) to long-recognised general regional priorities, which include the need to characterise and define wares using analytical techniques to establish the origins, products, production centres and distribution of diagnostic ceramics, and;

d) to the specific west Midlands research framework which comments that 'It is still very difficult to establish scientific programmes of research for investigating materials such as pottery, in order to establish trade routes and areas of economic connectivity' (http://www.iaa.bham.ac.uk/research/fieldwork_research_themes/projects/wmrrfa/seminars.htm).

3.3 Specific aims and objectives

3.3.1 Characterisation

e) to establish how Midlands purple and Cistercian-type wares produced at the different major manufacturing centres in the west Midlands can be distinguished from each other, using standard fabric characterisation methods alongside chemical and petrographic analyses, and;

f) to test if, and how, traded ceramics from consumer sites (the test case) can be related back to the production sites, using the same fabric characterisation methods.

3.3.2 Providing a reference resource and knowledge transfer

g) to establish a publicly accessible database for the west Midlands production sites which can assist historic environment professionals and others across the region in their response to both existing collections, and to new material from production and consumer sites, and ensure efficient use of resources; and which can be exploited and built on by future analyses of ceramics in this region and beyond, thus providing a preliminary interpretative model which can be tested and revised; for example, by developing typologies of forms and decoration for the different production centres, by examining potential links between fabrics and forms/decoration as a means of distinguishing production centres and products, by recording pottery from consumer sites to begin to define the market areas of the major west Midlands production centres, and by exploring potential links between the precursors of Midlands purple and Cistercian-type wares, and those wares themselves and their respective date ranges inform the wider understanding, in a period of general ceramic transition, of the chronology and beginnings of this major industry, in the region and beyond, since potteries throughout Yorkshire and the Midlands manufactured similar wares, and;

h) to publicise the reference resource.

3.3.3 Documenting the beginnings of a chronological framework

i) to compare the characterisation data from two domestic consumption sites with uniquely early and securely-dated material, that is Midlands purple and Cistercian-type wares (and including late medieval/transitional wares, the precursors and/or contemporaries of Midlands purple) stratified in pre-Dissolution (pre-1538) and Dissolution-period contexts at Bordesley Abbey (Worcs), and the Austin Friars Leicester using the same characterisation data as for production sites, and;

j) so to provide firm dating for the use of these wares and firm indicative *taq* dates relating to the inception of (at least some areas) of the industry; and point the way forward regarding any remaining problems of dating of these wares.

4. Business case

Core objective (as defined in SHAPE 2008) of this project is 1A-1-A1, sub-programme 11111.510 (for details, see above).

The commissioning of this project has been extremely timely. The good deposits of wasters from very recent excavations in the west Midlands (Burslem, Stoke-on-Trent: see Boothroyd and Courtney 2004; and at Ticknall: see Boyle and Rowlandson 2006-8) have served to emphasise how little we still know about the early years of this industry and the market for its products. Work undertaken for the project design highlighted a considerable amount of unpublished (grey literature) material from Wednesbury for example, and the existence of manufacturing locations at Jackfield (Shrops) and West Bromwich (historically Staffs, now West Midlands). Anne Boyle's recently completed PhD thesis (Boyle 2006) provides a comparative database for the area to the east and north of the study area: this considers Cistercian ware in Yorkshire and the east Midlands, from both production and consumer sites, and includes typological and some fabric (x20 macroscopic descriptions) analyses.

This project is focused on fabric analysis, and comparison of material from production sites with traded ceramics from stratified contexts on select consumer sites. It builds on work carried out recently in the region, including limited ICPS (by Alan Vince) of Ticknall sherds. This project tackles a significant aspect of the latest medieval to earliest post-medieval period when ceramic traditions evidently change, but when and why is not understood. As such, it will benefit archaeologists and historians working in the west Midlands and beyond.

In order to maximise the practical usefulness of the database for heritage professionals, ICPS and ceramic petrography are included, and linked with standardised photography and x20 microscopical fabric descriptions.

By employing a combination of techniques it is possible to offer others working in the historic environment sound practical guidance on characterisation, as well as a reference base as far as possible. Both the guidance and the reference base can feed directly into cost-effective enhancements to developer-funded and other research in the region on both production and consumer sites. The results from the various techniques will show which, whether macroscopic or microscopic, will most reliably identify the products of different manufacturing centres at both production and consumer sites. If, for example, a particular fabric cannot be reliably distinguished macro/microscopically, this would constitute valuable background knowledge that should inform the decisions of curators and managers as to the best use of resources for future projects.

5. Methods

A definition of Midlands purple and Cistercian-type wares

Midlands purple and Cistercian-type wares are well-established ceramic ware types which have a wide currency, and are typical of the late medieval/early post-medieval transition (16th century) in the west Midlands.

Midlands purple – this has been commonly identified on many sites across the English Midlands (including east; eg Lincoln (Young and Vince 2005, 225–7), and elsewhere, for instance to the north (eg Cumberpatch 2004). A similar ware was exported from northern France into southern England from about the mid 15th century (Normandy stoneware). Typically the Midlands purple fabric is wheel-thrown, very hard, tending on stoneware, and usually unglazed, the high firing temperature often providing a metallic sheen, most usually on the outside surface. It was produced in a wide range of vessel types most of which are modelled around the jar form. Midlands purple did not really continue much past the 17th century nor evolve into any other ware, unless the stonewares of the later 17th century and onwards can be seen as its descendants. In fact, it is arguably the first home-produced stoneware, though this possibility seems to have been assiduously avoided by most writers on ceramics, possibly as it is such an un-prepossessing ware.

Cistercian-type ware – this has been commonly identified on many sites across the Midlands (both east and west). This ware type was first identified in northern England where its association especially with Cistercian monasteries led to its name. The fabric is typically a wheel-thrown standard earthenware fabric, and it was always glazed, usually in a darkish colour, and quite often moderately decorated in discrete motifs applied in white clay. In northern England (see eg Cumberpatch 2004) the range of forms was extensive but they were all usually modelled around small multi-handled drinking vessels (often termed *tygs*; cf Brears 1971 classification of types). In the Midlands the same type of vessels were also used, though the impression here is that there may have been less variation in form-types. This general type continued to be made into the 17th–18th centuries when it is typically referred to as blackware. In this report the term *Cistercian-type* ware is preferred for the later 15th- to 16th-century ware, as the northern Cistercian ware has an extensive form repertoire which, so far, has not been demonstrated as being fully paralleled by the Midlands material.

5.1 Strategy

The overall strategy comprised identifying as many as possible of the Midlands purple and Cistercian-type wares production centres in the west Midlands (see specific criteria below), where samples could be sought for a suite of techniques to be applied. In addition two consumer sites were included to allow for the possibility of testing the production sites results against identical data from consumer sites to ascertain whether provenances could be established for any of the latter material, and especially if this translated into the recognition of any visual reference keys to aid identification.

5.2 Preparation for visiting collections and selection (Stage 1)

A definitive list of relevant collections was drawn up in consultation with museum curators, archaeologists and ceramic specialists; and the KAC (2003) national list of kilns was also consulted. The initiation stage of this project had identified the existence of possible manufacturing locations at Jackfield and West Bromwich, bringing the number of production areas up to six, but giving a better geographical spread. However, it turned out that material from both these areas was not available to the project (see below). In the course of the sampling it also turned out that the definitive list drawn up at this stage was not accurate (see more below).

The criteria used to establish which collections holding material from the production areas to visit were:

- their being representative of the Cistercian and Midlands purple ware traditions;
- the presence of misfired vessels/wasters, wherever possible, and;
- the likely date being 15th–16th century (more specifically 15th to first half of the 16th century wherever possible).

A *pro forma* record was produced for recording each fabric type through all stages of collection and analysis in order to ensure consistent data collection and characterisation (following Peacock 1977 and PCRG 2009). Additional data regarding form and decoration were recorded following MPRG guidelines re form classification (MPRG 1998), with reference to more specific typologies (eg Ford 1995; Boyle 2006) if appropriate.

Holders of the collections were explicitly asked about:

- quantity, ie how much material they hold (Cistercian(-type) and Midlands purple wares);
- accessibility (whether held centrally or in an out-store) and method of retrieval (including associated records), and;
- opening hours.

Holders of the collections were sent a copy of the *pro forma* record to show the extent and types of data being collected. They were requested during the initial consultation stage (Stage 1) to authorise in principle:

- the release of sherds for analysis in the knowledge that this analysis will be destructive (ie making thin sections and ICPS sampling);
- the curation of the analysed sections in the project archive;
- the retention of the sherds themselves to form part of the project archive, and;
- the publication of the data derived from collections visits and their analysis.

Bordesley Abbey and Austin Friars Leicester material were included in order to represent consumer sites and these are arguably unique in the region in that their 15th-/16th-century Midlands purple and Cistercian-type wares were from well-dated pre-Dissolution and/or Dissolution deposits.

Project data for pottery will comprise all descriptive (both qualitative and quantified) data. These data will form part of the project archive and would be made available through the Worcestershire ceramics website, with links from the Bordesley Abbey website, as appropriate.

The list of relevant collections will form part of the project archive.

5.3 Collections and selection of samples (Stage 2)

The collections were each initially sent a formal letter explaining about the project and to arrange an appointment. Sampling of production areas for both Midlands purple and Cistercian-type ware was targeted to include, wherever possible:

- misfired vessels/wasters to try to ensure we are sampling ceramics actually manufactured at the production centre, and;
- ‘early’ production.

An attempt had been made at Stage 1 to identify the earliest material, in some cases identifying several relevant sites to select from at Stage 2. With several kilns, or more, possibly spread over a wide area and operating contemporaneously, producing broadly visually similar wares, as apparently at Ticknall (Spavold and Brown 2005) and Chilvers Coton (Mayes and Scott 1984), this pilot study cannot be comprehensive, sampling every kiln or possible production area. So choices were made on the basis of information collected at Stage 1, the targeted sampling criteria (set out above) and, frequently, in terms of what was most readily available for sampling during the actual visits, given the time restrictions.

During each visit, fabric types were further defined prior to the selection of material for analysis. The working definition of identifiable fabric types developed on the spot formed the basis of selection. Many criteria were considered during the sampling:

- the size of assemblages and the associated available information (preferably extensive in both cases);
- ideally each possible fabric-type was sampled by the selection of 5–10 sherds per type as candidates for the next analysis stage (Stage 3);
- and samples for analysis were, wherever possible, a minimum of approximately $10cm^2$ to allow **all** analyses to be carried out on the same sherd.
- where available decorated sherds were sampled (especially Cistercian-type), especially if this was distinctive and so could be taken to provide additional grounds for the identification of the products of a particular production centre;
- when sampling Midlands purple ware, consideration was given to selecting material from different sites where the size and form of vessel (ie medium-sized jar) was as consistent as possible, and;
- no material was to be selected for analysis where there was a dubious attribution to any given site.

Sampling of the production sites was deliberately undertaken **before** tackling the consumer site sampling – the intention being to have the best opportunity of potentially recognising provenancable material from the latter.

Sherds were only chosen in consultation with the curatorial staff, and care was taken that where individual sherds were removed, they could be tracked back to where they were extracted from – therefore a paper trail was carefully established leading back to the bags/boxes whence the material had been extracted from. Curatorial staff were reminded of the contents of the initial formal letter with regard to minimally destructive analysis and the retention of sherds for the project archive. Sherds were listed on a consent *pro forma* (discussed and agreed with Sarah Jennings at the Stage 1 meeting), which the curator signed; a copy was then given to the curator. The individual museum's material movement or other relevant forms were also signed.

During the sampling visit, photographs were taken for future reference of any potentially useful groups of sherds or near-complete vessels, or to reflect the range of fabrics, glazes or forms, in a collection/assemblage.

Not included in this project

Systematic typologies of forms and/or decoration were beyond the scope of this project. However, all other factors being equal, broad form typologies and decoration (as in eg the presence of applied and stamped white clay pads seen on some Cistercian ware vessels) did play a part in the final selection of individual sample sherds to represent the fabric-type.

5.4 Analysis (Stage 3)

During this stage a final choice was made of samples for scientific analysis following visual (macro- and microsopical) description of fabrics of sampled sherds. In the case of the production centres a minimum number of five sherds from different vessels (for explanation of this see below) were selected on the basis of their being representative, and, in addition to a unique sample number, each type of pottery was also assigned a 'group' number according to each site represented. In the case of sherds from consumer sites the same approach was adopted but sherds were selected in 'groups' according to fabric identifications given prior to this project. Where both sample and group references are given together they are in this order (ie 58-15 is sample 58, group 15).

5.4.1 Analytical techniques

A combination of analytical techniques was used with the emphasis on techniques to characterise rather than to provenance the wares. The integrated approach to characterisation is intended to provide a clear picture of the degree of differentiation offered by the various techniques, both descriptive and scientific. A key consideration for the outcome of the project is the nature and degree of correlation between the results of the different scientific analyses, and their correspondence (or not) with visual and/or x20 microscopical differences.

All analyses were carried out on the same sherd. The same sherds as were used for ICPS for the Ticknall potteries (19 analysed samples; sherds held by Dr A Boyle) were re-used in this project, and so were subject to the other techniques applied during this project.

Standardised photography

Selected samples were photographed in the presence of a colour test card and scale, to enable the accurate balancing of colours – this was intended to constitute a working aid rather than publication-quality images.

x20 microscopy

Microscopical (x20) fabric descriptions were produced in accordance with MPRG (1998) recommended guidelines on form definitions. Detailed description of clays and inclusions was in accordance with Prehistoric Pottery Research Group (2009) guidelines.

ICPS

ICPS analysis of the fabric of pottery gives a chemical fingerprint, and thus information on its source, reflecting the clay(s) from which it was made (eg Hughes 1991). It differs from petrological methods in producing an overall composition of the whole fabric, which is, therefore, mainly that of the clay. In that sense ICPS tends to complement petrology, as the latter describes mainly the mineral inclusions within the clay. Even when different inclusions are seen in two groups of pottery, if the overall chemistry is similar, it is likely that both derive from the same general clay source, though clay processing may also have added or removed mineral inclusions making ceramic fabrics appear more different than they really are.

A minimum of five samples per fabric group is needed to ensure that the results of the statistical examination of the ICPS analyses (see eg Hughes 2008) are valid, and this was generally achieved (see Table 11, and Table 3).

Existing ICPS data for the Ticknall potteries (19 analysed samples; data, courtesy of Derbyshire Archaeological Society, available from the AVAC database created by Alan Vince) were also used, and integrated with the new data. Here 19 samples had been analysed for two sites: Peat's Close x 9 (ie MP x 4, Cistercian-type x 5); and Church Lane x 10 (ie MP x 5, Cistercian-type x 5). The results of these analyses had already successfully detected variation in clays used, admirably illustrating the potential of this technique.

The initiation stage indicated that increasing the number of samples analysed for some manufacturing locations would considerably enhance the usefulness of the project's results. Twenty samples for Burslem (two sites), and Wednesbury (several sites) match the number analysed by ICPS for Ticknall (two sites); a total of 15 samples for Nuneaton included 10 for the Chilvers Coton (Mayes and Scott 1984) site. The number of samples selected for analysis were sufficient to reasonably expect a sound and useful knowledge base to result. Splitting a small number of samples, for example 10 samples (5 Midlands purple and 5 Cistercian-type ware), between several sites, possibly some distance apart, within a production area would increase the likelihood of ending up with a large number of fabric types and individual chemical 'fingerprints'; however sometimes this was necessary (eg Wednesbury) due to only limited material being available.

When Stage 3 was well under way, it finally became clear that a change of laboratory was necessary. ICPS sample analysis was to have been carried out by Nick Walsh at Royal Holloway (RH), but in late 2009 Nick Walsh's access to the ICPS facility ceased. Michael Hughes (MJH) had lengthy discussion with staff at Royal Holloway as to how ICPS analysis would be managed in the future. Quality assurance and timescales were clearly important issues. A very large proportion of the scientific analysis of archaeological ceramics in the UK in recent decades has been carried out by Nick Walsh here through external ICPS contracts involving both (the late) Alan Vince and Michael Hughes (Alan Vince had analysed over 5000 ceramics by ICPS at RH). It became clear that it would not be possible to try to continue to use RH and keep this project moving. Therefore, after exploring other potential facilities, the sample ICPS analysis was transferred to Reading University, a decision based on comparative costs and turnaround times (see above for revised method). The change to the Reading University laboratory and new personnel meant that some details in the ICPS process had to be different (for details see Section 7.2) and some tasks were reallocated. Slices of sherds (needed for 71 samples due to hardness) were cut by John Coundon (in addition to the slicing and thin section preparation for R Ixer to carry out the fabric petrographic and glaze analysis); and MJH then removed the glaze from the slices, and sent the cleaned-up slices, plus powdered samples, plus 5 standard powders (for quality assurance), to Reading, where the slices were then crushed.

Reading finally analysed the powders by ICPS in one batch (Reading charged higher rates per sample if small part-batches, so all the ICPS finally had to be done in one batch, with no opportunity for stages and review).

Petrographic analysis

Ceramic petrography using thin sections of the fabric is useful for establishing the background geology of the clay source and any added temper, by describing mainly the mineral inclusions within the clay. Thin-section analysis attempts to establish the raw materials used by the potters, evidence for preparation of the clay, and the relationship of the visual groups to raw materials (ie were the groups produced by firing the same fabric in different ways or were different materials used for each group?).

It was intended, as stated in the PD, to incorporate the results of the ICPS analysis (data for Ticknall posted on the Alan Vince Archaeological Consultancy website) **and** thin section fabric analysis of sherds from Ticknall, Derbyshire, by Alan Vince, courtesy of AV and Janet Spavold, Sue Brown and the Derbyshire Archaeological Society which had funded the work. With Alan Vince's death in February 2009, R Ixer kindly agreed to take on the petrographic analysis for this project. In the course of the project, following on from AV's death, his archive was assessed, and the thin sections were found (and returned to Janet Spavold and Sue Brown), but no associated report was located. As a result the PD was updated to allow R Ixer to add these thin sections to his main batch so that all the petrographic work on the project has been done consistently by one person.

All the thin-section slides created for the purposes of the project will form part of the project archive.

The analysis of four samples of Midlands purple ware from Burslem (3 from the School of Art site and 1 from Market Place) had formed part of a thin-section analysis for various Burslem and Stoke ceramics done some years previously by Alan Vince (2003; avac2003105). These data were considered for possible use and integration with the new data, if the sherds could be identified in the collections and were suitable for reuse for other techniques in this project. However, only one of the samples (Market Place) was noted as production waste. These four thin sections were, therefore, excluded from the project because they represented a high risk (may not be locatable and/or suitable), and only one met the preferred criteria of being a misfired vessel/waster.

Relative merits of the scientific techniques applied

It is very highly fired wares (both Midlands purple and Cistercian-type wares fall into this category) from the production sites themselves that are the main focus of this project, with an emphasis on misfired vessels/wasters. It has been suggested by the project team's scientific advisor (Dr M J Hughes) that chemical 'elemental' analysis will yield more precise distinctions than thin sectioning. Chemical analysis potentially will differentiate not only between manufacturing centres but also between locations within a manufacturing area. In particular, chemical analysis should characterise more precisely very highly fired fine wares (ie, in this project, Cistercian-type ware misfired and waster vessels).

Ceramic petrography can complement ICPS as it can assist interpretation of ICPS data by explaining why certain elements show differences between groups and can suggest a (geological) region for production sites for ceramics of 'unknown' source from, for example, consumer sites (which ICPS does not do so well). This will be tested in this project by comparison of thin-section analyses of groups from production and consumer sites.

Thus, the application of fabric thin-section analysis was targeted, with an emphasis on the consumer sites; the number of samples was more limited than for ICPS analysis, but will still provide sufficient information across the production sites. The scientific members of the project team (M Hughes and A Vince) recommended two fabric thin sections per fabric type.

Following the recommendation of Alan Vince that the written description of thin-section fabric analysis should be available for consultation alongside the thin-section slide, it is intended that the fabric thin-section slides will form part of the project archive (see 6.2.4).

The Burslem study (see above; Vince 2003) had previously illustrated some of the potential limitations of fabric thin-section analysis in terms of this project. The thin sections here had revealed that all the samples (Midlands white wares, late medieval orange ware and Midlands purple) had a restricted range of inclusion types and other characteristics, and were best described as a single group. They did confirm that there was clearly a deliberate selection of different coloured clays for different wares. Without access to samples of unworked clay, either from the production site or from nearby geological outcrops, it was impossible to be absolutely certain about the source of the raw materials and their preparation. The main unsolved question was the origin of the clay used for the School of Art Midlands purple ware. This study pointed out that thin sections may give a misleading impression here, since two of the three samples were partially or completely vitrified, which will have substantially altered the appearance of the texture in thin section; it may be, however, that a different, iron-rich, clay was chosen for the Midlands purple ware precisely because of its low fluxing point. It was concluded that chemical analysis of the groups with iron-rich groundmasses would show conclusively whether the latter was the case.

Glaze analysis

Reflected and transmitted light petrography using polished thin sections of glazed pottery has only rarely been used in archaeology to identify and describe the opaque phases within the glaze (Ixer 2008). A polished thin section is more expensive to make than an ordinary thin section and the time to analyse them is also greater as there are so many more data available in polished thin section (R A Ixer, pers comm). This technique was tested on a small sample of the glazed fine wares (Cistercian-type ware).

General

Data tables created and/or updated during this stage will form part of the project archive.

5.5 Reporting and dissemination (Stage 4)

Reporting will comprise the following stages (not necessarily in this order):

a) Integrate and review the results from this project with other existing evidence.

b) Prepare characterisation data, and commentary for online publication.

c) Prepare full report. On-line publication is intended (as part of the Worcestershire (WHEAS) ceramics website http://www.worcestershireceramics.org which is based around the Worcestershire fabric type-series); and through the Bordesley Abbey Project's website (http://www.reading.ac.uk/bordesley).

d) Prepare short report for print publication (*Medieval Ceramics*).

e) Prepare summary reports for: OASIS; sponsor (RAI); stakeholders.

Material will be returned to collections where appropriate.

Archive deposition, as a publicly accessible physical resource, will be at WHEAS offices (there is currently no designated regional centre for such resources), including the thin sections.

6. Stage 2 – sample collection

6.1 Sampling production centres

General

Many of the risks identified for this stage in the PD transpired: museum closure (ie time delay); elements of material/archive missing/unavailable at time of visit; elements of material/archive missing/unavailable in long term; team member unavailable or temporarily unavailable; organisations who refused to make their data publicly accessible. This occurred despite specifying in advance as closely as possible the material/archive to be seen, and consent being explicitly sought before collections were visited regarding material and data. As a result even carrying out the visits was very time consuming, and then revisiting, revision of the selection, and rearrangement and extension of the timetable all also became necessary.

In some cases (eg Nuneaton) decisions were taken not to sample more complete vessels, as this would have been to the detriment of displayable items. Again, even where more complete items were sampled at this stage they were sometimes not included in destructive analytical sampling for similar reasons.

It was discovered as the project got underway that petrographic analysis has been previously carried out on a range of Staffordshire wares by R Ixer but these data turned out to relate to 17th-/18th-century wares.

Place	Site name	Publication ref
Burslem, Stoke-on-Trent	Burslem Market Place	Boothroyd and Courtney 2004
Burslem, Stoke-on-Trent	Burslem School of Art	-
Chilvers Coton, Nuneaton	Chilvers Coton 1967, site 15, kiln 34 (east of Bermuda Road)	Mayes and Scott 1984, 20, fig 4 and 63–4; KAC 2003
Chilvers Coton, Nuneaton	11 Bermuda Road, Chilvers Coton (site code NB99)	Coutts 1999
Chilvers Coton, Nuneaton	16–22 Bermuda Road, Chilvers Coton (site code NCC79)	Scott ?unpublished
Chilvers Coton,	Harefield Lane/The Lawns (site code	Mayes and Scott 1984, 21, fig 5

Nuneaton	NHL): site 18, kilns 40, 42 (Scott)	
Ticknall	Church Lane (Spavold and Brown 2005, site 2)	Boyle and Rowlandson 2006–8
Ticknall	Peat's Close (Spavold and Brown 2005, site 6)	Boyle 2002–3
Wednesbury	Lower High Street	assessment only: Mitchell 2006
Wednesbury	Town centre (Morrisons)	work in progress
Wednesbury	Lower High Street service trenches	-
Wednesbury	Market Place	Hodder 1992
Wednesbury	Meeting Street	Coates 2006; Cherrington and Richmond 2006

Table 1 Production centre sites included in the analysis

6.1.1 Burslem, Staffordshire

Source: The Potteries Museum & Art Gallery, Hanley, Stoke-on-Trent; visited 4 August 2009

Midlands purple and Cistercian-type samples were identified and obtained from both the Market Place Burslem site (published as Boothroyd and Courtney 2004) and the School of Art Burslem site (excavator Jon Goodwin); in both cases (thanks to information received) we were able to locate and select sherds from the earliest part (late 15th-/early 16th-century) of the stratigraphic sequence. Material from other Burslem sites was considered but rejected, including Swan Bank (evidently a consumer site not a production site as has been claimed); Hulton Abbey material (consumer site discussed in the PD) was not available for comparison/consultation (inaccessible on health and safety grounds).

6.1.2 Nuneaton, Warwickshire

Source: Warwick Museum, Warwick; visited 30 July 2009

Midlands purple samples were obtained from Keith Scott's excavations at Harefield Lane (site ref NHL; Mayes and Scott 1984); no Cistercian-type from Scott's excavations were located during this visit; additional Midlands purple samples were obtained from 11 and 16–22 Bermuda Road (NB 99 and NCC 79 respectively) and Haunchwood sites in Chilvers Coton (the latter site not included in analysis).

The Chilvers Coton pottery from Philip Mayes' and Keith Scott's 1967–71 excavations (published as Mayes and Scott 1984) proved to not be all at Warwick, as indicated by Warwick Museum; this mistake then necessitated an additional trip to Nuneaton where the Mayes material was finally successfully located at Nuneaton Museum (see below), together with more material from Scott's long-running (1960s onwards) fieldwork apart from that published in Mayes and Scott (1984), though museum records could not readily confirm this was the case.

Source: Nuneaton Museum; visited 10 August and 10 November 2009

Midlands purple and Cistercian-type samples from Philip Mayes' 1967 excavations site 15 kiln 34 (Mayes and Scott 1984), and a single Cistercian-type ware sherd from NCC 74 (?Recreation Ground, Chilvers Coton; ?Scott) were identified; the latter was not included in the analysis.

Overall there proved to be only a small quantity of Cistercian-type ware, essentially the published illustrated material (Mayes and Scott 1984, 160, fig 108), and virtually nothing else of this type, whereas there was an extremely large amount of Midlands purple from Mayes' (and Scott's) 1967–71 excavations, and later fieldwork in the area, though in the latter case it is presently unclear whether less thorough publication may account for this impression. However, extensive and rather prolonged negotiation was then required to get official permission for our selected sherds to be released; arrangements were finally forthcoming for this release in November 2009. A second personal visit was then required to collect the material.

6.1.3 Jackfield, Shropshire

Source: Ironbridge Museum/Archaeology Unit

The Unit was contacted on several occasions but it proved impossible to make any arrangements for a visit during the lifetime of the project.

6.1.4 Ticknall, Derbyshire

Source: Janet Spavold's and Sue Brown's personal collection was visited at Ashby de la Zouch (Leics) on 29 June 2009; Alan Vince had previously sampled sherds of Midlands purple and Cistercian-type ware from the Peat's Close and Church Lane sites (Vince 2007), and these sherds were collected for fabric description, and the relevant thin sections made available for study (see above).

Cistercian-type samples from Peat's Close and Church Lane sites, and Midlands purple samples from Church Lane were identified and collected. These two production sites seem to be two of the earliest of the many in the Ticknall area, ie first half of the 16th century or earlier, and they are forming the focus for on-going research into this industry (Boyle 2002–3; Boyle and Rowlandson 2006–8; Vince 2007).

Sue Brown also indicated vessels in the Austin Friars Leicester publication (Mellor and Pearce 1981) which might be Peat's Close and Church Lane, Ticknall, products, based on form and decoration.

6.1.5 Wednesbury, Staffordshire (Sandwell, West Midlands)

Source: Wednesbury Museum/Ironbridge Unit (via Graham Eyre-Morgan, County Archaeologist); visited 28 July and 20 August 2009

Midlands purple and Cistercian-type samples were obtained from the Lower High Street sites, and Midlands purple samples from Market Place and Meeting Street sites (Hodder 1992).

6.1.6 Wednesbury, Staffordshire (Sandwell, West Midlands)

Source: Birmingham Archaeology visited 12 August 2009

Cistercian-type was obtained from Morrison's site, Town centre.

6.1.7 West Bromwich, Staffordshire (Sandwell, West Midlands)

The original Oak House assemblage seemed to be unlocatable at Wednesbury Museum (assistance from Graham Eyre-Morgan), and more recent nearby fieldwork (Lindsey Archaeology; Field and Glover 2009) had produced such a very small amount of Cistercian-type production waste that this assemblage could not be definitely considered as indicative of production. No samples were, therefore, selected.

6.2 Sampling consumer sites

The experience of the material from the production areas did, as suggested in the PD, influence the choice of sherds from consumer sites (see Bordesley below). For more detailed background to the consumer assemblages used see Appendix 1.

6.2.1 Bordesley Abbey, Worcestershire

Source: Bordesley Abbey Project (c/o Susan M Wright), 28 August 2009

Bordesley Abbey: church and E cloister; exterior eastern cemetery			
Unpublished areas only: aisles, W choir & nave 82–94; E cloister walk 77–78; cemetery	**Highly fired (no. sherds)**	**Midlands purple (no. sherds)**	**Cistercian (no. sherds)**
post-Dissolution/post-16th C contexts	7	-	31
Dissolution per 5 contexts	6	2	53
pre-Dissolution per 4A, 4B, 4C contexts	14	1	29
Total no. sherds	27	3	113
Previously published E choir (Hirst *et al* 1983, 87–9)			
pre-Dissolution per 4C contexts	-	-	7

Table 2a Midlands purple and Cistercian wares, and their highly-fired precursors, on consumer sites included in the analysis: summary table of the context and quantity of the assemblages initially identified for analysis at Bordesley Abbey

Samples of Cistercian-type only were selected (Table 2a). These were selected to cover the variation in glaze and fabric identifiable in Cistercian-type, and to include wherever possible stratified pre-Dissolution rather than Dissolution-period sherds from the church and cemetery (mainly unpublished). Having seen so much Midlands purple recently, the four sherds previously classified as Midlands purple from the church and cemetery excavations were rejected as not sufficiently highly fired, and so not typical of Midlands purple seen elsewhere.

6.2.2 Austin Friars Leicester

Source: Jewry Wall Museum, Leicester; visited 18 August 2009

Austin Friars Leicester: second cloister area			
Principal occurrences by phase: Dissolution and earlier (Woodland 1981, 85)	**'Transitional MP' (no. vessels)**	**Midlands purple (no. vessels)**	**Cistercian (no. vessels)**
phase 9A Dissolution contexts	99/105	30	169
phase 7A pre-Dissolution 15th C contexts	13	11	19
phase 5A pre-Dissolution	5	3	1
phase 4B pre-Dissolution	6	5	-

Table 2b Midlands purple and Cistercian wares, and their highly-fired precursors, on consumer sites included in the analysis: summary table of the context and quantity of the assemblages initially identified for analysis at Austin Friars Leicester

Midlands purple and Cistercian-type samples were obtained (Table 2b). The curatorial staff located some, but not necessarily all, of the material published by Woodland (in Mellor and Pearce 1981) in their new (2007) store during our visit; what could not readily be identified was the actual published pottery. It was not possible to spot in the boxes made available in the store's visitor area anything more than the odd sherd that might be in the publication, that is none of the apparently whole pots were found. Some sherds had drawing numbers, but only in one or two cases did they also have a publication number (which did seem to be probably the number used in the published Austin Friars report); nor could a concordance list of drawing numbers and publication numbers be found. Anne Boyle had previously visited Leicester Museum (2001/2) as part of her research (Boyle 2006) but had identified possible Ticknall pots mainly in the Austin Friars publication, rather than in the collections (no complete or near-complete pots were seen then either; A Boyle, pers comm).

Fortunately, we were able to obtain sufficient Midlands purple and Cistercian-type from the two key phases we had identified from the report, that is for phases 7A (pre-Dissolution) and 9A (Dissolution period). It was possible to sample four out of the five Midlands purple fabrics identified in the report; several of these fabrics can be seen from the report to be numerically very minor elements and, in line with this, for two fabrics we were only able to collect <4 sherds.

6.3 Review

Stage 2 was successfully accomplished, despite the problems encountered with the various collection visits of this stage. It proved very much more time-consuming than anticipated. The project is a pilot study and one which clearly necessitates a considerable degree of flexibility with regard to the detailed approaches and outcomes compared to the theoretical framework set out in the PD. As envisaged, there could be several relevant sites in a production area to select from and the working definition of identifiable fabric-types developed on the spot, forming the basis of selection.

Having seen such a large quantity of these wares now, and over a wide geographical area, we retained the option to slightly increase numbers analysed where fabrics are very variable, as seemed to be the case on our preliminary visual examination during the selection process at Stage 2. However, in the end this option was not exercised.

In addition to the four major production sites, identified at the outset of the project, the initiation (PD) stage had identified the existence of possible manufacturing locations at Jackfield and West Bromwich, bringing the number of production areas up to six in the west Midlands. Jackfield remained the one with least information and in that sense the most uncertain. West Bromwich was finally never established as a samplable site. However, in the end neither of these additional sites provided samples (see above).

The Stage 2 visits revealed that two production areas in particular are associated with very large collections, namely Nuneaton and Wednesbury; at the latter, because largely more recent, there was a very considerable amount of unpublished material. However, due to the inexact nature of archaeological finds recovery and difficulties of access to storage areas this impression may not reflect the true respective scale of these industries, and so the relative scale of the different west Midlands production centres remained unclear despite visiting the relevant repositories.

At the programmed end of this stage it became necessary to reallocate and re-schedule the thin section analysis – access to the Alan Vince archive also became temporarily unavailable which was pertinent to the Ticknall material. Assessment of the Alan Vince Archaeological Consultancy archive (EH-funded) was very promptly undertaken and eventually it proved possible to locate the required thin sections (see above).

7. Stage 3 – analysis and results

7.1 Fabric definition (*by* D Hurst)

The fabrics of all sherds collected during Stage 2 were classified by eye (macrospically, and microsopically at x20 magnification), and as a result 30 separate fabrics were identified and recorded. Sherds were photographed, and for a representative sherd of each fabric a fresh break was photographed as a working aid. See Appendix 2 for detailed fabric definitions.

7.2 Chemical analysis by inductively-coupled plasma spectrometry (*by* M J Hughes)

Further detailed technical data relating to Figures 2–7 is available in Appendix 3.

7.2.1 Introduction

The present investigation used inductively-coupled plasma atomic emission spectrometry (ICP-AES) and ICP mass spectrometry (ICP-MS) to analyse the fabric of a range of Cistercian-type and Midlands purple pottery as part of a characterisation project of these wares. In order to consider what fresh information inductively-coupled plasma spectrometry (ICPS) might give on both the production and distribution of the two pottery types within the region, samples were taken from a number of production centres in the west Midlands (represented by two or more sites), and also from two key consumer sites to test whether, following characterisation, comparison of their chemistry with the production centres could establish provenance.

ICPS analysis of the fabric of pottery gives a chemical fingerprint and thus information on its source, reflecting the clays from which it was made. It differs from petrological methods in producing an overall composition of the whole fabric, mainly that of the clay. This tends to complement petrography which describes mainly the mineral inclusions within the clay. Even when different inclusions are seen in two groups of pottery, if the overall chemistry is similar, it is likely that both derive from the same general clay source, though clay processing may have added or removed mineral inclusions from the fabric. A minimum number of typical representatives from each source group need to be tested.

In the present case, there are a limited number of production centres to be tested, but there are both Cistercian-type and Midlands purple wares from each centre, and more than one site within each production centre was tested. Production centre 'sample groups' thus represent both different sites and the two different ware types (eg sample nos 21–25 = sample group 6 = Burslem [production centre] Market Place [production site] Cistercian-type [pot type]; sample nos 26–30 = sample group 7 = Burslem [production centre] Market Place [production site] Midlands purple [pot type]). In the case of the two consumer sites, each group represents an individual fabric type previously identified (prior to the beginning of this project) among that site's Cistercian-type and Midlands purple pottery (Section 6.2 and Appendix 1).

Hence the overall number of groups is quite large, and the numbers analysed were restricted to a maximum five examples of each group, which is about the minimum to get consistent results.

A summary list of the 90 samples selected for ICPS analysis is shown in Table 11 (REA sample references). Typical examples of both types of pottery were included from the production centres of Wednesbury (south Staffs, now Sandwell West Midlands), Burslem (Stoke-on-Trent, Staffs) and Nuneaton (Warws), and the consumption site of Austin Friars Leicester (Leics); only Cistercian-type ware was analysed from the other consumption site of Bordesley Abbey (Worcs). Existing ICPS data were available for comparison for 19 Cistercian-type ware samples from the production centre of Ticknall (Derbys; Vince 2007), and these samples are also included in Table 11. In addition, samples of two Midlands white ware vessels and a roof tile from the late 14th-century and later, white ware production site of Sneyd Green, near Stoke (Staffs), had been previously analysed by this author and are used for comparison (Hughes 2004).

(Floor tiles from Bordesley Abbey received detailed analytical investigation in projects involving neutron activation analysis in the 1980s on ceramic tiles from the English Midlands (Hughes *et al* 1982; Leese *et al* 1986; Stopford *et al* 1991). Analytical work – petrological examination of thin sections and neutron activation analysis – was also carried out on tiles, kiln furniture and local clays from Bordesley Abbey by I Freestone and M J Hughes: Astill and Wright 1993.)

7.2.2 ICPS analysis

Of modern chemical analytical methods for ceramics, inductively-coupled plasma atomic emission spectrometry (ICP-AES) and mass spectrometry (ICP-MS) are especially useful as they are widely available, rapid, produce accurate results on many elements and at relatively low cost per sample (the sample dissolution and instrumentation are described in Thompson and Walsh 1989, and Potts 1987). The atomic emission version (ICP-AES) analyses all the major elements in ceramics (except silicon which can be estimated by difference if needed), plus a good cross-section of the trace elements including the transition metals and some rare earth elements. Even more recently, the mass spectrometry version of inductively coupled plasma spectrometry (ICP-MS) has been introduced in a few ceramic provenance studies in archaeology (eg Tykot and Young 1996; Hughes 2008). Its principal strength is the ability to measure very low concentrations of trace elements in materials, including elements which cannot be measured by ICP-AES. The latter include the heavy elements uranium and thorium, the alkalis rubidium and caesium, and the whole suite of rare earth elements. All of these have proved themselves important discriminating elements in ceramic provenance studies previously carried out by neutron activation. The same solution prepared from each sherd for ICP-AES can be used for ICP-MS, eliminating the need for any extra sample preparation, and this was carried out in this project.

Powdered samples were obtained from 19 of the 90 sherds by drilling with a tungsten carbide drill, the normal method used by the author for sample preparation for ICPS. However, for the other 71 sherds, the pottery was too hard to drill and it was necessary to slice a thin fragment from the sherd. The fragment was then abraded with a diamond-embedded cylindrical drill bit to remove the glaze as far as possible. The fragments were then sent to the analytical laboratory of Archaeological, Forensic and Environmental Scientific Services (AFESS), School of Human and Environmental Sciences, at the University of Reading, where they were crushed by hand to powder before analysis, together with drilled samples supplied as powder. The drill/slice sample preparation method is shown for each sample in Tables 3 and 11.

As well as the 90 Cistercian-type and Midlands purple samples for analysis, we included five portions of a Certified Reference Material (NBS679 Brick Clay – produced by the US National Institute for Standards and Technology, Washington DC) placed at regular intervals in the analysis batch but without identification to the laboratory as such. The latter were to act as analysis control samples, and also to provide a means of later comparing the present ICPS results to previous analyses, of Ticknall and Sneyd Green pottery, made by the School of Earth Sciences, Royal Holloway, University of London, laboratory (Vince 2007 and Hughes 2004 respectively). The Certified Reference Material (CRM) results are given in full at the foot of Table 3.

The weighed samples were placed in small individual Teflon (PTFE) beakers, treated with a mixture of hydrofluoric and nitric acids, and heated overnight on a hotplate to dissolve the ceramic. The acids were evaporated off and the residue dissolved in further nitric acid and made to volume with ultra high quality water. The laboratory reported, however, that the samples seemed to need further acid digestion. Perchloric acid was added as a further stage, which then appeared to complete the dissolution. This latter acid is regularly used to dissolve geological samples by other laboratories, for instance Royal Holloway (Walsh and Thompson 1989; Potts 1987). The solutions were analysed in batches on an automated ICP-AES and ICP-MS system. The full set of ICPS analysis results is given in Table 3.

Table 3 Results on all the ICPS analyses carried out in this project

sample refs	ICPS analysis	Group	slice/drill	place	site	pot type	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn	Na	Ni	P	Pb	Sc	Sr	Ti	Zn	Ce 140	Co 59	Cs 133	Dy 163	Er 167	Eu 153	Gd 158	Ho 165	La 139	Nd 143	Pr 141	Rb 85	Sm 152	Tb 159	Th 232	Tm 169	U 238	V 51	Y 89	Yb 174
1	REA01	1	drill	Wednesbury	Lower High Str	cist	37899	278.4	14856	71.6	55.8	34805	23736	77.4	13944	915	2531	43.0	813	27871	9.6	61.6	4799	70.5	77.55	39.48	6.53	3.53	1.98	1.45	6.29	0.80	39.62	31.89	8.79	88.62	6.10	0.85	15.26	0.41	2.73	114	15.07	1.93
2	REA02	1	drill	Wednesbury	Lower High Str	cist	42531	307.6	15729	80.5	40.1	37856	27734	74.2	16147	866	2858	32.0	535	3484	8.4	62.9	5223	80.3	62.00	22.28	5.48	2.36	1.07	1.00	4.64	0.43	24.09	22.97	5.93	92.72	4.58	0.50	7.55	0.15	2.29	109	8.22	0.91
3	REA03	1	drill	Wednesbury	Lower High Str	cist	74414	434.2	16487	82.9	42.0	42958	28937	81.8	15754	1110	2909	39.6	954	730	12.5	93.3	5331	105.1	65.54	30.14	6.36	2.74	1.24	1.17	5.15	0.49	26.50	26.94	7.00	99.74	5.44	0.58	9.56	0.17	2.62	105	9.45	1.07
4	REA04	1	slice	Wednesbury	Lower High Str	cist	92324	459.0	26193	79.3	34.8	41976	29285	72.1	19042	935	2734	51.0	625	35004	14.3	109.4	5349	74.9	73.19	17.44	8.40	4.36	2.15	1.52	6.88	0.78	34.22	32.17	8.45	103.50	6.61	0.83	11.05	0.31	2.71	117	18.55	2.11
5	REA05	1	slice	Wednesbury	Lower High Str	cist	86248	443.9	20803	76.4	52.4	40503	28538	65.9	18112	1117	2593	41.0	602	47669	13.3	95.4	4927	72.0	70.86	18.23	8.19	3.92	1.97	1.50	6.57	0.78	34.44	32.35	8.52	107.51	6.41	0.83	16.45	0.33	2.82	117	16.19	1.91
6	REA07	2	slice	Wednesbury	Town centre	cist	94051	330.0	1969	61.8	36.3	41711	20279	58.3	7565	597	2281	28.4	397	26677	17.2	50.6	5024	42.6	49.32	8.48	6.94	3.63	2.05	1.43	4.72	0.79	22.24	20.89	5.49	81.31	4.41	0.64	11.31	0.35	2.47	159	23.34	2.15
7	REA08	2	slice	Wednesbury	Town centre	cist	46435	239.6	1760	43.7	42.6	48114	10122	24.2	1879	1300	351	19.8	155	15185	10.6	<LOD	4258	40.2	55.78	30.92	2.94	2.19	1.34	0.79	3.36	0.53	16.75	14.56	3.82	41.83	2.98	0.45	6.04	0.25	2.01	176	10.09	1.34
8	REA09	2	drill	Wednesbury	Town centre	cist	61396	367.9	12019	67.4	39.0	36709	22538	67.9	15182	866	2154	42.3	654	562	11.9	64.3	4587	135.5	60.79	24.67	6.89	2.82	1.31	1.14	5.00	0.51	26.51	26.34	6.89	92.21	5.19	0.58	8.99	0.18	2.27	92	10.84	1.18
9	REA10	2	slice	Wednesbury	Town centre	cist	85651	383.2	7882	66.2	36.2	45619	24142	58.3	11699	1129	2277	34.6	495	40896	14.3	72.9	4498	64.0	55.03	14.80	7.51	3.25	1.68	1.19	5.08	0.62	27.85	24.89	6.65	107.70	5.15	0.63	9.49	0.24	1.99	111	14.82	1.60
10	REA11	2	slice	Wednesbury	Town centre	cist	83175	399.6	11016	75.4	31.4	45676	27626	66.3	15499	1206	2356	45.1	564	9542	11.8	79.3	4865	93.1	60.78	19.72	6.56	3.42	1.84	1.27	5.54	0.67	25.57	26.38	6.58	63.45	5.48	0.69	8.00	0.27	2.53	115	12.97	1.76
11	REA12	3	drill	Wednesbury	Lower High Str service trenches	MP	58226	141.9	1061	40.1	35.4	31359	7704	46.1	2172	83	836	12.6	160	1239	9.2	21.9	5238	27.1	15.82	23.06	3.17	1.16	0.78	0.26	1.17	0.26	6.43	4.91	1.31	47.25	0.99	0.18	4.55	0.11	2.63	136	4.88	0.82
12	REA13	3	slice	Wednesbury	Lower High Str service trenches	MP	119245	260.1	2045	59.1	98.1	30888	14390	89.4	4472	588	916	35.2	310	3184	20.9	30.7	6363	62.0	42.13	14.52	5.49	2.55	1.40	0.87	3.60	0.51	13.08	15.16	3.70	38.78	3.38	0.46	7.30	0.20	2.85	174	8.45	1.35
13	REA14	3	drill	Wednesbury	Lower High Str service trenches	MP	64626	143.0	1067	55.2	100.4	64291	9604	53.0	2492	251	655	34.8	454	2352	9.8	<LOD	5675	73.4	43.57	32.23	3.57	1.20	0.58	0.43	2.02	0.21	6.97	7.51	1.93	43.59	1.68	0.23	3.87	0.08	2.63	161	2.87	0.56
14	REA15	3	slice	Wednesbury	Lower High Str service trenches	MP	134925	307.8	2350	56.9	65.5	57137	14148	59.4	4634	1234	838	32.6	306	1670	27.9	33.7	6826	75.9	71.34	20.07	5.61	4.56	2.42	1.72	7.11	0.89	25.83	31.81	7.64	45.48	6.89	0.87	10.94	0.35	3.72	216	15.97	2.39
15	REA16	3	slice	Wednesbury	Lower High Str service trenches	MP	104875	249.5	3205	50.2	52.4	65013	11578	43.5	5094	317	966	13.9	224	1676	22.9	36.6	5206	35.8	36.10	7.49	5.33	2.51	1.43	0.83	3.45	0.51	19.01	16.84	4.48	65.26	3.48	0.45	9.88	0.21	3.27	154	11.17	1.43
16	REA17	4	slice	Wednesbury	Market Place	MP	133204	329.8	950	63.1	77.8	60340	15958	45.6	5410	279	1124	21.1	265	8075	25.8	34.8	6519	43.6	93.10	14.21	7.21	6.67	3.66	2.22	9.78	1.33	43.84	45.16	11.37	88.58	9.34	1.26	12.33	0.55	2.71	199	28.72	3.64
17	REA18	4	slice	Wednesbury	Market Place	MP	153283	484.8	1788	100.6	77.6	79454	22525	55.7	8069	648	1704	40.4	324	2788	30.5	60.1	8253	74.2	84.28	24.75	9.36	6.29	3.37	2.12	8.98	1.23	36.54	40.84	10.15	90.37	8.76	1.17	14.00	0.48	4.63	230	23.50	3.23
18	REA19	4	slice	Wednesbury	Market Place	MP	108785	377.8	1386	79.2	58.7	46556	18064	41.7	6591	1421	1034	59.8	203	4592	19.6	42.4	6052	87.5	65.83	37.76	6.46	4.49	2.45	1.44	6.35	0.90	25.83	27.68	6.93	56.61	6.05	0.85	8.81	0.36	3.42	160	16.40	2.38
19	REA20	5	slice	Wednesbury	Meeting Street	MP	121499	249.7	1193	56.8	45.8	53906	14049	46.6	4070	655	879	21.9	277	8312	24.3	29.2	6508	55.7	51.29	14.64	5.59	3.43	1.93	1.08	4.62	0.70	18.28	19.57	4.79	46.53	4.27	0.62	8.97	0.30	2.82	202	12.04	1.99
20	REA21	5	slice	Wednesbury	Meeting Street	MP	80717	331.2	2496	37.0	61.9	56996	18254	37.9	6208	762	3125	84.9	<LOD	6514	16.5	63.7	4899	688.4	71.52	24.31	6.45	4.38	2.25	1.58	6.94	0.85	36.87	33.60	8.61	99.40	6.60	0.83	9.20	0.31	2.27	150	20.32	2.06
21	REA22	6	slice	Burslem	Market Place	Cist	118994	327.1	674	99.9	38.8	25173	12711	32.3	3377	162	659	31.8	194	42953	20.9	35.6	7463	23.7	54.49	8.14	5.92	3.51	2.01	1.29	5.32	0.75	23.21	25.01	6.37	46.48	5.26	0.65	10.09	0.31	3.30	185	13.84	2.11
22	REA23	6	slice	Burslem	Market Place	Cist	123154	368.7	1035	98.4	36.5	45990	13823	49.2	3070	294	768	32.0	304	9119	18.5	48.4	7502	39.8	37.19	9.97	5.03	2.45	1.48	0.75	3.04	0.50	14.04	13.29	3.43	34.96	2.89	0.43	8.55	0.22	3.17	189	8.86	1.47
23	REA24	6	slice	Burslem	Market Place	Cist	110949	328.2	988	78.8	38.2	46063	13830	42.1	3639	237	789	33.6	287	46721	19.4	49.0	7228	41.5	43.83	9.04	5.95	2.49	1.34	0.91	3.66	0.50	18.88	18.41	4.89	46.33	3.81	0.46	8.96	0.22	3.13	174	9.29	1.49
24	REA25	6	slice	Burslem	Market Place	Cist	131209	721.1	1903	102.2	90.3	46138	15036	94.4	5401	206	876	60.7	360	28626	24.3	73.0	6729	79.3	81.96	14.03	7.27	4.65	2.43	1.80	7.52	0.93	41.58	37.95	9.97	99.83	7.45	0.88	11.89	0.36	3.28	199	20.94	2.36
25	REA26	6	drill	Burslem	Market Place	Cist	69246	287.7	763	85.2	51.4	28064	12678	39.3	3563	104	819	37.7	213	833	11.5	39.1	8189	55.7	30.74	27.08	3.88	1.32	0.66	0.52	2.12	0.25	13.37	10.66	2.88	69.53	2.06	0.26	5.55	0.09	3.00	178	4.58	0.58
26	REA28	7	slice	Burslem	Market Place	MP	127870	376.0	1615	105.8	44.7	52960	15058	65.6	3699	340	1022	44.1	417	12336	20.1	76.3	6541	137.6	46.87	10.15	5.36	3.44	1.99	1.03	4.36	0.71	20.29	20.18	5.26	40.34	4.25	0.61	9.93	0.30	3.42	176	13.05	2.03
27	REA29	7	slice	Burslem	Market Place	MP	130380	393.4	1114	103.3	54.7	52745	14985	62.9	4700	182	962	62.9	325	277	22.1	58.5	7578	89.0	47.65	14.81	5.74	2.75	1.38	1.14	4.32	0.52	19.36	22.20	5.59	41.20	4.59	0.54	7.65	0.19	3.50	208	8.67	1.31
28	REA30	7	slice	Burslem	Market Place	MP	109088	293.0	619	89.1	44.1	52166	14094	37.0	3220	241	855	31.4	247	6934	16.8	39.5	6688	76.4	33.73	8.67	5.26	2.73	1.66	0.64	2.83	0.56	16.66	12.95	3.63	37.79	2.58	0.43	8.08	0.25	3.21	164	10.68	1.74
29	REA31	7	slice	Burslem	Market Place	MP	120998	373.5	1451	97.5	49.0	46612	14783	56.4	4053	175	974	58.0	305	113	18.1	48.5	6291	75.1	40.38	13.76	4.95	3.06	1.72	1.03	4.01	0.61	14.77	17.92	4.46	28.24	3.99	0.55	6.52	0.25	3.49	179	9.72	1.72
30	REA32	7	slice	Burslem	Market Place	MP	140492	488.5	1261	92.4	65.1	56279	15276	60.8	5225	371	967	48.9	326	3325	25.2	53.4	6542	189.6	88.09	14.48	8.53	5.41	2.93	1.89	8.14	1.08	44.64	40.25	10.40	94.56	7.88	1.01	12.51	0.43	3.40	210	24.85	2.89
31	REA33	8	slice	Burslem	School of Art	Cist	102409	366.4	372	88.3	34.3	42816	13044	23.3	3963	149	876	32.0	227	53807	18.4	34.4	7167	48.0	41.00	10.87	4.74	2.85	1.72	0.85	3.65	0.59	22.03	17.35	4.75	69.85	3.47	0.49	9.36	0.25	2.48	173	13.51	1.71
32	REA34	8	slice	Burslem	School of Art	Cist	28685	132.2	994	88.1	23.3	38668	9137	28.2	2712	143	905	72.6	305	54799	4.2	26.7	7622	56.0	15.66	10.67	3.94	0.75	0.54	0.29	0.93	0.22	7.78	3.78	1.24	56.18	0.77	0.17	12.00	0.14	2.52	173	3.28	0.60
33	REA35	8	slice	Burslem	School of Art	Cist	62568	256.8	526	80.9	33.6	35560	10098	27.3	2816	93	770	38.8	173	41590	8.0	<LOD	7146	87.4	26.12	9.61	4.05	1.18	0.76	0.42	1.56	0.23	9.38	7.14	1.87	73.05	1.56	0.20	5.66	0.10	2.23	173	4.99	0.71
34	REA36	8	slice	Burslem	School of Art	Cist	51181	197.2	602	88.2	41.1	37628	11607	29.0	3337	113	843	64.0	344	45780	8.0	28.3	7429	49.4	18.07	10.32	3.29	1.39	0.79	0.42	1.53	0.31	9.77	7.38	1.95	55.95	1.52	0.25	6.10	0.14	2.50	180	5.12	0.84
35	REA37	8	slice	Burslem	School of Art	Cist	70249	276.9	927	87.6	31.4	44227	8454	27.0	2969	256	788	66.6	520	99932	8.9	25.8	7145	80.0	25.12	14.26	3.25	1.14	0.70	0.35	1.49	0.23	7.92	5.55	1.55	52.26	1.28	0.19	5.94	0.10	2.31	167	4.90	0.70
36	REA38	9	slice	Burslem	School of Art	MP	81664	197.4	966	81.7	65.2	66730	13518	41.1	3412	119	771	38.1	535	729	11.0	35.9	6274	93.5	33.58	8.28	5.32	1.84	1.08	0.53	2.41	0.37	13.63	10.51	2.83	71.41	2.14	0.32	5.77	0.15	3.35	188	8.06	1.04
37	REA39	9	slice	Burslem	School of Art	MP	87978	241.9	1288	90.0	68.8	54754	14226	46.9	4057	137	844	50.4	428	1190	13.0	38.7	6777	79.2	40.56	8.60	5.79	2.18	1.25	0.68	3.02	0.45	15.54	13.43	3.48	78.32	2.73	0.39	6.66	0.18	3.51	205	9.27	1.24
38	REA40	9	slice	Burslem	School of Art	MP	72624	206.3	1204	83.2	62.2	58847	12568	35.9	4069	192	772	63.2	502	391	12.1	36.8	6584	69.9	39.95	12.84	4.48	2.22	1.17	0.71	3.15	0.43	13.70	13.33	3.36	70.65	2.87	0.40	6.02	0.17	3.31	186	7.30	1.15
39	REA41	9	slice	Burslem	School of Art	MP	104746	240.4	729	100.5	63.7	55830	11868	57.6	3569	157	818	67.0	315	3259	15.6	44.8	7172	95.2	30.62	11.04	5.71	2.01	1.25	0.55	2.34	0.43	12.77	10.84	2.89	51.55	2.16	0.33	6.43	0.18	3.55	215	6.70	1.28
40	REA42	9	slice	Burslem	School of Art	MP	99948	272.2	781	78.9	54.2	44017	11111	53.8	3448	159	772	71.2	279	497	17.5	34.5	5922	79.4	40.87	8.72	4.97	2.37	1.16	0.78	3.51	0.45	17.91	17.45	4.46	60.25	3.51	0.44	8.02	0.16	2.80	167	8.02	1.13
41	REA43	10	drill	Nuneaton	Chilvers Coton (Mayes)	Cist	86511	430.0	1214	126.3	90.4	53428	14280	67.6	4250	253	789	64.1	278	111	14.5	66.3	8938	78.9	68.80	49.61	8.56	3.00	1.35	1.32	5.66	0.53	30.36	28.94	7.59	89.92	5.85	0.65	10.15	0.18	3.05	147	10.63	1.11
42	REA44	10	slice	Nuneaton	Chilvers Coton (Mayes)	Cist	89254	390.8	1247	134.7	73.7	62951	14814	77.7	4668	203	864	155.8	300	26210	17.8	80.9	8981	78.9	69.84	17.23	12.23	3.00	1.42	1.38	5.50	0.55	35.07	28.79	7.62	105.50	5.67	0.62	11.32	0.20	3.09	180	13.10	1.30
43	REA45	10	slice	Nuneaton	Chilvers Coton (Mayes)	Cist	93501	376.5	1279	157.5	153.1	64008	14930	80.9	4626	204	929	101.7	398	19147	16.8	81.0	9369	89.8	72.58	18.51	11.36	3.49	1.90	1.24	5.46	0.70	35.44	27.93	7.32	98.46	5.37	0.67	10.57	0.28	3.44	182	14.39	1.80

44	REA46	10	slice	Nuneaton	Chilvers Coton (Mayes)	Cist	74492	409.4	1386	109.8	49.9	50011	13301	61.3	3950	239	783	86.9	289	61323	12.8	64.6	7880	67.5	56.78	21.75	7.02	2.72	1.19	1.15	4.76	0.46	22.98	23.18	5.94	84.01	4.78	0.56	8.71	0.17	2.61	154	9.37	1.06
45	REA47	10	slice	Nuneaton	Chilvers Coton (Mayes)	Cist	48516	182.0	916	105.2	39.1	41889	11330	52.4	2982	105	530	122.1	229	46468	6.5	37.7	7647	53.8	25.64	9.18	5.70	0.94	0.50	0.38	1.63	0.19	8.05	7.44	1.90	59.23	1.55	0.19	4.68	0.08	2.49	151	3.41	0.50
46	REA49	11	slice	Nuneaton	Chilvers Coton (Mayes)	MP	94409	409.0	1202	129.6	39.6	61826	17402	94.2	4879	209	1318	83.3	307	8578	15.2	80.0	7630	90.7	69.86	18.55	10.17	2.64	1.27	1.19	4.88	0.50	30.60	25.94	6.87	90.43	5.06	0.55	9.33	0.19	3.02	154	10.34	1.25
47	REA50	11	slice	Nuneaton	Chilvers Coton (Mayes)	MP	71271	465.3	6401	136.5	51.6	55594	16215	100.9	5458	263	1456	113.1	270	3936	10.9	95.9	8251	106.7	64.86	19.70	7.84	2.42	1.11	1.05	4.47	0.44	23.69	22.14	5.80	82.00	4.37	0.50	8.24	0.15	3.46	153	8.57	1.03
48	REA51	11	slice	Nuneaton	Chilvers Coton (Mayes)	MP	71144	309.9	1969	141.6	48.6	61918	16725	75.6	4106	158	1114	116.1	280	6770	11.1	60.5	8655	68.3	58.66	17.22	7.97	2.20	1.14	0.86	3.91	0.42	22.45	19.12	4.99	76.64	3.76	0.44	7.73	0.16	3.14	156	8.12	1.07
49	REA52	11	slice	Nuneaton	Chilvers Coton (Mayes)	MP	89365	457.4	2143	126.4	56.3	56027	21246	89.7	5436	178	1427	69.0	235	518	14.5	85.5	6788	162.2	72.15	16.43	10.96	2.98	1.44	1.16	5.31	0.56	30.40	28.02	7.34	110.47	5.42	0.61	10.65	0.20	3.30	159	11.37	1.34
50	REA53	11	slice	Nuneaton	Chilvers Coton (Mayes)	MP	53820	322.0	1343	133.0	48.0	54064	17762	85.1	4690	307	1158	83.5	201	1921	8.3	62.0	8061	76.4	51.96	22.94	7.28	1.75	0.81	0.78	3.26	0.31	17.10	15.89	4.16	73.55	3.24	0.36	5.48	0.11	3.21	145	4.88	0.74
51	REA54	12	slice	Nuneaton	Harefield Lane	MP	117176	273.1	4040	93.5	111.2	34441	16816	273.7	4756	172	936	104.3	207	2217	18.0	84.6	5711	66.1	74.89	9.97	11.80	4.44	2.25	1.56	6.91	0.84	31.80	31.53	8.15	71.38	6.70	0.86	11.77	0.32	3.93	178	16.97	2.09
52	REA55	12	slice	Nuneaton	Harefield Lane	MP	109995	328.4	2165	94.5	86.5	38899	17456	235.2	4470	177	872	86.6	218	446	18.4	58.1	5743	23.7	95.61	11.65	10.86	5.42	2.67	1.82	8.23	1.01	38.22	39.59	10.20	67.80	8.15	1.04	12.99	0.37	4.26	173	20.03	2.48
53	REA56	12	slice	Nuneaton	Harefield Lane	MP	113495	416.4	7066	80.2	213.3	44055	16715	179.5	4401	247	960	67.5	218	1866	19.9	120.9	5460	36.4	90.86	11.74	12.95	5.12	2.47	1.92	8.33	0.95	43.63	40.88	10.74	91.38	8.36	1.03	13.63	0.35	3.50	157	20.56	2.31
54	REA57	13	slice	Nuneaton	11 Bermuda Road	MP	91267	1002.7	8246	83.1	293.3	49764	10793	176.6	3175	161	1150	109.1	4132	3600	15.3	114.6	5657	524.1	67.70	32.08	6.89	6.79	2.97	2.33	10.56	1.25	29.22	37.41	8.75	42.55	8.52	1.34	10.62	0.37	5.64	189	26.69	2.31
55	REA58	14	slice	Nuneaton	Chilvers Coton (Scott) (NCC79)	MP	68111	309.2	1444	109.1	57.4	39643	18858	152.8	4755	180	1011	100.4	258	273	8.8	64.2	6236	50.8	51.78	16.22	9.44	1.67	0.72	0.78	3.30	0.30	18.04	17.48	4.53	56.93	3.43	0.36	5.12	0.09	3.89	184	4.44	0.60
75	REA59	19	drill	Leicester	Austin Friars	Cist	78592	410.7	16515	80.1	64.6	43460	28176	70.5	17188	1134	3655	37.4	547	19207	13.7	100.3	5035	233.8	91.90	42.74	9.14	4.25	2.10	1.54	7.29	0.77	43.82	37.32	9.89	118.70	7.10	0.82	10.76	0.31	2.99	120	16.61	1.89
76	REA60	19	drill	Leicester	Austin Friars	Cist	41197	345.5	1196	86.5	21.6	39455	17807	145.8	3632	225	1097	37.6	295	5643	5.4	59.7	5489	88.2	61.25	41.36	13.12	1.68	0.76	0.71	3.24	0.31	17.00	15.91	4.19	93.24	3.19	0.35	6.75	0.11	2.76	115	5.15	0.69
77	REA61	19	drill	Leicester	Austin Friars	Cist	61293	369.2	9294	75.8	45.4	45672	27894	72.6	11676	1532	2791	43.4	810	602	10.1	70.7	5083	73.5	59.58	29.70	4.70	2.10	0.91	0.93	4.14	0.37	21.14	21.69	5.69	58.09	4.30	0.45	7.74	0.12	2.56	111	6.70	0.75
78	REA62	19	drill	Leicester	Austin Friars	Cist	76731	591.9	2553	95.0	36.2	48157	25037	170.3	5997	434	1540	49.9	183	3138	12.3	97.1	6853	109.2	95.36	58.22	17.09	3.71	1.69	1.64	7.35	0.67	39.89	38.36	10.06	131.02	7.66	0.79	11.99	0.23	3.18	138	13.25	1.46
79	REA63	19	drill	Leicester	Austin Friars	Cist	86308	616.6	1175	80.3	16.6	43784	24598	150.3	5223	147	1244	28.4	347	118	14.5	114.6	6334	24.0	86.43	51.35	16.37	3.55	1.76	1.39	6.38	0.66	42.37	37.26	10.05	121.28	6.79	0.73	13.02	0.25	2.80	116	14.71	1.60
80	REA64	20	slice	Leicester	Austin Friars	MP	85761	1064.9	1165	127.5	49.9	37363	23029	231.5	4745	152	1544	101.9	398	547	12.7	195.9	5332	30.1	61.02	11.28	11.29	1.39	0.65	0.79	2.82	0.26	16.29	16.25	4.19	88.88	3.31	0.29	7.15	0.09	2.47	165	4.42	0.56
81	REA65	20	slice	Leicester	Austin Friars	MP	114420	1487.8	3335	108.8	105.3	41499	16533	335.1	4046	141	1378	89.0	284	270	15.8	104.0	5972	72.6	73.97	14.04	13.86	1.96	0.86	1.24	4.34	0.34	32.60	27.20	7.41	65.94	5.14	0.45	10.09	0.11	3.29	149	6.44	0.69
82	REA66	20	slice	Leicester	Austin Friars	MP	117226	1120.4	5051	101.8	143.8	29075	17029	342.1	4343	127	1046	79.4	194	193	18.1	120.9	5924	120.7	81.92	13.52	15.56	3.13	1.54	1.41	5.45	0.59	41.79	33.62	9.12	87.70	6.17	0.62	13.43	0.22	3.57	157	12.59	1.47
83	REA67	20	slice	Leicester	Austin Friars	MP	104913	1719.6	5048	103.7	133.0	30904	20772	350.7	4773	211	1053	107.7	274	456	16.2	143.0	5767	39.3	79.07	17.66	13.86	3.26	1.68	1.56	5.42	0.64	31.38	28.52	7.77	78.55	5.99	0.66	11.69	0.26	3.97	162	12.27	1.56
84	REA68	20	slice	Leicester	Austin Friars	MP	92009	973.3	999	124.6	34.7	21267	16639	358.3	4284	72	1035	78.1	175	477	13.0	64.8	6549	130.7	67.83	9.67	13.23	2.71	1.45	1.14	4.25	0.54	29.14	24.92	6.84	79.59	4.69	0.51	10.08	0.21	4.58	179	9.49	1.41
85	REA69	21	slice	Leicester	Austin Friars	MP	115485	589.3	838	127.0	73.4	44535	19044	356.6	4632	157	982	66.9	345	942	17.1	77.5	6655	154.4	87.34	15.73	15.53	4.19	2.28	1.44	6.09	0.83	34.18	31.77	8.54	89.77	6.22	0.78	13.03	0.33	4.47	166	16.09	2.22
86	REA71	21	slice	Leicester	Austin Friars	MP	114218	720.9	1251	137.2	83.3	35790	18655	458.8	4123	142	918	123.8	283	982	16.5	77.3	6972	54.7	79.82	16.60	13.27	3.40	1.81	1.21	5.03	0.66	27.63	25.35	6.87	73.17	4.98	0.63	11.64	0.26	4.74	187	12.57	1.72
87	REA72	21	slice	Leicester	Austin Friars	MP	97010	1101.0	1252	128.4	43.4	28118	16364	420.7	4878	163	1102	76.1	331	7224	14.5	85.2	6390		78.68	18.85	11.57	2.80	1.55	1.16	4.63	0.55	35.25	26.14	7.28	82.81	4.66	0.54	10.46	0.23	3.84	163	10.87	1.57
88	REA73	21	slice	Leicester	Austin Friars	MP	123250	649.1	1893	125.2	84.1	44666	18786	343.2	4784	118	1014	74.3	262	1347	19.5	92.5	6747	63.7	83.24	14.83	17.49	3.79	2.02	1.41	5.73	0.74	37.53	32.70	8.98	102.85	6.12	0.70	14.05	0.30	4.42	170	15.36	2.01
89	REA74	21	slice	Leicester	Austin Friars	MP	130076	1054.4	1953	122.0	60.7	34309	17040	417.8	4694	163	1137	92.0	295	1736	20.7	112.6	6438	53.9	101.10	18.65	17.25	4.34	2.28	1.75	7.08	0.83	52.34	41.11	11.26	103.52	7.44	0.84	14.74	0.32	4.00	173	18.39	2.14
90	REA75	22	slice	Leicester	Austin Friars	MP	77399	536.0	<LOD	134.5	58.1	31125	17144	447.3	4216	121	1052	75.7	314	3639	10.3	51.4	6973	13.7	49.20	14.45	11.85	1.82	1.00	0.61	2.58	0.37	15.59	11.60	3.24	65.33	2.33	0.32	6.66	0.15	4.45	184	5.28	0.97
91	REA76	22	slice	Leicester	Austin Friars	MP	51086	653.3	970	119.9	55.3	30450	14810	404.3	3637	94	1003	79.5	214	314	6.1	53.4	6638	75.5	31.10	15.17	12.15	1.15	0.69	0.43	1.50	0.23	9.95	7.10	2.03	55.19	1.49	0.19	4.27	0.10	3.85	166	3.26	0.72
92	REA77	22	slice	Leicester	Austin Friars	MP	67614	610.1	1125	125.6	57.4	22422	15070	480.3	4114	154	1218	71.2	366	4247	7.5	59.9	6893	110.0	39.06	16.24	12.08	1.52	0.87	0.57	2.09	0.31	14.99	10.93	3.11	62.47	2.15	0.27	6.23	0.13	4.08	189	4.52	0.90
93	REA78	23	slice	Leicester	Austin Friars	MP	69219	260.7	3634	105.0	50.6	42633	19632	154.4	6880	95	1858	99.5	611	2708	8.2	88.1	5094	146.5	66.80	16.62	6.88	2.87	1.25	1.02	4.81	0.52	25.87	24.67	6.60	98.96	4.74	0.58	8.12	0.16	2.74	119	8.13	1.00
94	REA79	24	slice		Bordesley Abbey	Cist	74383	272.2	2641	53.5	61.2	65984	20575	51.0	8364	1002	1888	66.9	176	3805	14.6	59.6	5328	124.6	62.71	29.61	5.61	3.16	1.68	1.06	4.72	0.62	22.30	20.92	5.47	86.09	4.39	0.57	7.70	0.24	2.50	190	11.77	1.61
95	REA80	25	slice		Bordesley Abbey	Cist	42924	172.8	1219	40.4	45.7	50879	13070	39.9	4439	226	1522	104.5	287	7670	4.9	<LOD	4707	48.6	37.03	7.35	4.29	1.33	0.82	0.40	1.90	0.28	12.43	8.77	2.35	60.95	1.70	0.23	4.37	0.12	2.71	133	5.22	0.85
96	REA81	25	slice		Bordesley Abbey	Cist	61956	272.3	1898	44.7	68.6	60026	15806	56.0	5555	633	1807	115.4	259	12534	11.6	33.2	4758	122.8	45.89	9.99	5.28	2.05	1.28	0.63	2.92	0.43	16.40	13.18	3.53	78.56	2.66	0.38	6.40	0.18	2.86	137	8.69	1.24
97	REA82	26	drill		Bordesley Abbey	Cist	86221	447.5	25400	77.0	33.7	41433	30643	66.7	22927	970	3251	38.2	692	6874	13.7	92.6	5229	65.7	80.40	38.74	9.68	4.56	2.54	2.00	7.42	1.27	39.95	35.10	9.65	125.78	7.29	1.30	19.96	0.80	3.34	104	17.80	2.33
98	REA83	26	slice		Bordesley Abbey	Cist	43050	296.5	5269	67.7	37.5	38560	23703	62.3	12442	1038	2368	73.6	457	38645	5.5	46.0	4566	157.4	60.12	15.74	6.95	1.74	0.84	0.67	3.25	0.33	16.50	15.33	4.09	89.15	3.12	0.36	4.94	0.13	2.12	113	7.09	0.92
99	REA84	26	slice		Bordesley Abbey	Cist	45931	373.5	10956	69.2	52.5	39375	23157	63.7	12435	914	2499	97.1	503	24090	8.5	64.3	4629	122.1	69.29	18.22	5.05	2.52	1.24	1.03	4.80	0.45	26.67	24.66	6.41	69.30	4.77	0.52	6.66	0.16	2.58	112	7.66	1.07
100	REA85	26	drill		Bordesley Abbey	Cist	88989	465.7	20533	75.0	37.4	45023	30231	67.5	20219	1041	2862	38.3	656	5450	14.1	92.1	5135	66.7	73.40	42.23	9.28	3.63	1.73	1.43	6.45	0.66	36.07	32.51	8.55	121.21	6.41	0.73	10.43	0.23	2.41	105	15.76	1.52
101	REA86	26	drill		Bordesley Abbey	Cist	98731	430.9	1961	83.9	175.7	46623	28010	160.1	5110	269	1841	50.7	406	13794	14.8	166.0	3774	82.1	87.85	38.34	10.69	3.14	1.50	1.61	6.48	0.69	44.54	38.42	10.16	145.46	7.17	0.79	12.13	0.35	1.89	121	12.29	1.44
102	REA87	27	drill		Bordesley Abbey	Cist	99725	476.8	9601	88.3	28.4	50863	31492	93.1	26524	854	2255	43.4	477	230	16.5	72.6	5010	63.2	67.23	57.86	11.43	3.55	1.73	1.36	6.01	0.66	34.57	31.86	8.50	133.76	6.25	0.72	11.30	0.23	2.67	124	15.16	1.52
103	REA88	27	drill		Bordesley Abbey	Cist	73054	492.8	14365	79.1	40.5	40527	28122	71.0	15259	1360	2625	41.8	498	298	12.5	85.4	4908	150.0	73.14	44.53	8.27	3.42	1.58	1.36	5.96	0.63	32.70	31.56	8.23	108.27	6.24	0.70	9.84	0.22	2.44	107	13.42	1.41
104	REA89	28	slice		Bordesley Abbey	Cist	40466	184.8	2281	51.9	75.1	48888	17170	62.3	6050	349	1436	49.1	222	7467	6.3	39.2	5379	75.4	40.99	10.24	4.49	1.47	0.83	0.48	2.10	0.32	12.27	9.12	2.47	62.78	1.85	0.30	7.18	0.16	2.80	171	5.20	0.85
105	REA90	28	slice		Bordesley Abbey	Cist	41933	222.2	3198	46.9	67.3	52837	15130	45.9	6082	596	1372	51.3	247	55573	6.5	37.6	4177	103.2	39.15	9.87	3.88	1.35	0.74	0.49	2.24	0.25	12.70	10.83	2.81	59.96	2.07	0.26	4.35	0.11	2.04	132	4.73	0.61
106	REA92	28	slice		Bordesley Abbey	Cist	70069	262.3	1378	50.9	31.0	40892	14617	51.2	5282	291	1443	103.5	183	35921	13.1	37.9	4625	82.0	44.97	7.21	5.86	2.59	1.62	0.80	3.69	0.54	17.39	15.41	4.08	78.75	3.30	0.46	6.93	0.22	2.18	161	10.80	1.56
107	REA93	28	slice		Bordesley Abbey	Cist	69632	239.4	1733	51.0	41.8	61837	19370	39.9	8644	915	1659	69.6	140	46637	12.5	44.5	4940	86.0	69.47	27.69	6.39	3.30	1.80	0.97	4.38	0.65	20.10	16.82	4.45	87.15	3.72	0.57	5.99	0.29	2.31	174	12.98	1.89
108	REA94	28	drill		Bordesley Abbey	Cist	88697	462.0	17728	73.5	32.7	46892	29250	68.0	19035	1231	2802	42.2	592	3472	14.2	83.7	4895	74.9	76.23	36.17	9.11	3.51	1.63	1.47	6.55	0.66	36.47	33.62	8.89	122.24	6.66	0.75	10.57	0.22	2.32	109	15.14	1.45
109	REA95	28	slice		Bordesley Abbey	Cist	80730	292.0	1663	63.7	76.6	49597	16092	64.0	5356	451	1428	80.8	199	38950	13.9	57.2	5072	121.8	55.45	8.50	6.99	2.71	1.49	0.89	4.03	0.52	23.15	19.10	5.19	96.14	3.70	0.49	8.45	0.22	2.55	160	11.36	1.49

ICPS Method Limit of Detection (LOD)		297	24	1279	26	91	578	778	23	42	12	839	85	480	71	0.8	54	404	116	0.306	0.698	0.046	0.335	0.202	0.035	0.234	0.080	1.134	0.603	0.198	0.745	0.101	0.059	0.860	0.037	0.063	2	1.819	0.158			
NBS679 Certified Reference Material																																										
	REA06				86179	287.4	1336	93.6	32.8	87924	20861	62.6	5982	1530	1089	42.8	638	34	13.2	53.5	4659	111.1	57.47	22.15	5.59	3.25	1.80	0.86	4.40	0.66	16.57	18.19	4.42	92.34	3.94	0.58	8.39	0.26	2.61	151	11.66	1.78
	REA27				102355	413.0	2052	93.1	34.0	89156	20856	81.6	6915	1687	1265	53.9	473	263	20.1	65.3	5159	345.4	96.16	25.29	9.69	6.03	3.29	1.78	8.85	1.19	44.66	42.59	11.18	180.40	8.70	1.13	13.79	0.48	2.73	161	27.61	3.20
	REA48				103842	389.9	1452	90.2	30.9	88949	20206	61.5	6686	1604	1140	56.2	671	77	19.2	62.6	4613	114.7	84.66	21.80	8.88	5.29	2.85	1.57	7.83	1.03	38.39	38.12	9.81	158.27	7.71	1.00	13.09	0.41	2.61	142	24.25	2.77
	REA70				100305	401.0	2452	90.1	45.4	89944	21467	61.1	6904	1625	1372	46.8	545	22	18.4	71.7	4642	209.4	87.04	24.64	9.28	5.63	3.02	1.68	8.26	1.12	38.61	38.92	10.07	171.38	8.07	1.05	13.43	0.44	2.76	160	24.37	2.97
	REA91				106987	415.7	1381	91.3	25.6	93537	24039	60.1	7227	1660	1225	49.5	654	27	19.8	56.4	4581	95.1	90.60	23.75	9.36	5.58	3.04	1.67	8.33	1.11	41.80	41.72	10.66	171.74	8.08	1.06	13.72	0.42	2.71	150	25.14	2.92

ICP-AES element symbols: Al aluminium; Ba barium, Cr chromium; Cu copper; Fe iron, K potassium; Li lithium; Mg magnesium; Mn manganese; Na sodium; Ni nickel, P phosphorus, Pb lead; Sc scandium; Sr strontium; Ti titanium; Zn zinc.
ICP-MS elements: Ce cerium; Co cobalt; Cs caesium; Dy dysprosium; Er erbium; Eu europium; Gd gadolinium; Ho holmium; La lanthanum; Nd neodymium; Pr praesodimium; Rb rubidium, Sm samarium; Tb terbium; Th thorium; Tm thulium; U uranium; V vanadium; and Yb ytterbium.

The following comments were received from the Reading laboratory:

> ICP-AES elements ie Al to Zn
>
> 1) Samples marked "<LOD": the concentration in digest solution is less than the limit of detection (LOD) for the ICP-OES, so no significant amount of that element was found.
>
> 2) Elements identified by yellow shading in heading: some samples have values less than the "method" LOD based on repeated blank digestions. In publications they would be recorded as <LOD, but they may be useful in regression and multivariate statistical analysis. The method LOD values are given.
>
> ICP-AES elements ie Ce to Yb
>
> 3) The approximate "method" limits of detection were calculated on the basis of x5 dilution of the samples, which applied to 50 samples. Most samples had to be diluted further (up to x400) to avoid excessive Pb concentrations. The LOD would then be correspondingly higher.
>
> 4) Where a result is highlighted in yellow, it denotes that the digest solution concentration was less than the "method" LOD for solution concentration based on repeated blank digestions. They should normally be shown as less than the LOD, but for the purpose of multivariate data analysis, they may be useful.'

The laboratory also commented that the very high lead concentrations in some samples (over 10,000 ppm) caused problems with the ICP-MS instrument. This type of ICPS is highly sensitive, and is normally used to measure only low levels of trace elements. High amounts of lead in solution can cause damage or contamination to the instrument, so to prevent this, the solutions were considerably diluted before ICP-MS analysis (see above, Reading laboratory comment 3). The lead was unfortunately a contamination of the body fabric by either small amounts of glaze still attached to the solid slices crushed before analysis, or by lead compounds which had been volatilised during the glazing process into the body fabric beneath the glaze layer. The latter has been observed by the author in other cases when taking samples by drilling from lead-glazed pottery, when it has not been possible to sample significantly away from the glaze layer (the Cistercian-type wares were typically thin-walled vessels, glazed inside and out).

For interpreting the data, there were minimal implications for the multivariate statistics, chiefly because the statistics uses tens of elements to derive the principal components, and errors in a single element in a few samples have little impact. Also the fact that a series of samples of the same pottery group have low concentrations is more significant in statistical terms than the larger than normal errors for their measurement. Of the ICP-AES elements highlighted in yellow (Table 3), only calcium (Ca), nickel (Ni) and strontium (Sr) were used in the statistics, and the four <LOD missing values were replaced by the LOD values for the element. This has minimal effect on the statistics. Of the ICP-MS elements with results marked in yellow (Table 3), cobalt (Ce) and erbium (Er) were not used in the statistics. The values for the other ICP-MS elements in yellow were, however, used.

Comment on the ICPS results – a potential problem

The CRM results are shown in full in Table 3. While the first result (REA06) is fairly similar to the other four for the major and trace elements analysed by ICP-AES, except for aluminium, magnesium and scandium, it has lower concentrations than the other portions in the trace elements analysed by ICP-MS, including the rare earths and rubidium, thorium and yttrium. The average for the four consistent analyses is given in Table 4 for the elements in common with Royal Holloway's ICPS data. The most likely explanation for REA06 is incomplete dissolution of the sample, as most of the elements with lower concentrations are those present in the clay mineral matrix. The problems with dissolution were apparently not completely resolved for at least this one sample. A difficulty arises in deciding how many other of 90 pottery samples may also have been affected, but there is no way of ascertaining this because some pottery may have naturally contained low concentrations of many elements. The presence of a significantly higher amount of diluting temper (eg quartz) in a clay fabric would show a similar effect to an incomplete dissolution.

Table 4 ICPS analysis results on the five portions of certified Reference Material NBS679 Brick Clay included as check-standards in the analysis batches, plus the results obtained by Royal Holloway on the same standard, and the adjusted Ticknall and Sneyd Green data

Analyses on NBS679 Brick Clay

Reading ICPS	**Al**	**Ca**	**Cr**	**Fe**	**K**	**Li**	**Mg**	**Mn**	**Na**	**Ni**	**Sc**	**Sr**	**Ti**	**Ce 140**	**Co 59**	**Dy 163**	**Eu 153**	**La 139**	**Nd 143**	**Sm 152**	**V 51**	**Y 89**	**Yb 174**
mean (analyses REA 27, 48, 70 and 91 only)	103372	1834	91	90396	21642	66	6933	1644	1250	52	19.4	64.0	4749	89.6	23.9	5.63	1.67	40.9	40.3	8.14	153	25.3	2.96
standard deviation	2812	510	1	2137	1679	10	223	37	96	4	0.8	6.4	275	5.0	1.5	0.31	0.09	2.97	2.15	0.41	9	1.56	0.18
coefficient of variation (%)	2.7	27.8	1.5	2.4	7.8	15.7	3.2	2.3	7.7	8.2	3.9	9.9	5.8	5.6	6.4	5.4	5.2	7.3	5.3	5.0	5.8	6.2	5.9
Royal Holloway ICPS																							
mean (20 analyses)	109273	3063	109	97437	23832	79.7	8009	1840	1070	61.5	23.7	74.7	5345	100.2	23.5	6.3	2.0	49.6	47.3	9.65	162.0	37.1	3.78
standard deviation	5323	956	10.0	4391	1317	6.9	343	90	344	3.2	1.4	3.4	368	13.4	1.2	1.1	0.5	6.2	11.4	1.68	7.0	2.7	0.67
coefficient of variation (%)	4.9	31	9.1	4.5	5.5	8.7	4.3	4.9	32	5.2	6.0	4.5	6.9	13	4.9	17	23	12	24	17	4.3	7.3	18
factor to multiply Royal Holloway ICPS analyses by:	**1**	**0.599**	**0.833**	**0.928**	**0.908**	**0.829**	**0.866**	**0.894**	**1.168**	**0.839**	**0.816**	**0.857**	**0.888**	**0.894**	**1.018**	**0.889**	**0.831**	**0.824**	**0.852**	**0.843**	**0.946**	**0.682**	**0.783**

Ticknall and Sneyd ICPS analyses by Royal Holloway adjusted to be comparable to Reading ICPS analyses:

item no.		***group no.***	***type***	**Al**	**Ca**	**Cr**	**Fe**	**K**	**Li**	**Mg**	**Mn**	**Na**	**Ni**	**Sc**	**Sr**	**Ti**	**Ce 140**	**Co 59**	**Dy 163**	**Eu 153**	**La 139**	**Nd 143**	**Sm 152**	**V 51**	**Y 89**	**Yb 174**
Ticknall, Peat's Close																										
61	V4266 (A.Vince sample no.)	16	MP	137057	1078	114	70973	22884	354	9522	331	1870	57.9	22.9	81.4	10840	102.9	23.4	6.22	1.66	51.07	55.4	8.43	167.5	32.8	3.92
62	V4267	16	MP	119746	1317	102	64014	26517	240	9781	313	1986	52.0	18.8	123.4	8885	78.7	17.3	3.55	0.83	42.01	44.3	5.90	159.9	20.5	2.35
63	V4268	16	MP	136104	1078	99	43975	23157	384	9089	223	1986	57.1	21.2	87.4	10218	128.8	22.4	8.00	2.49	63.42	68.2	12.65	151.4	38.2	3.92
64	V4269	16	MP	117258	958	90	45831	26063	217	10647	286	1870	33.6	18.0	86.5	9151	67.1	15.3	3.55	1.66	40.36	42.6	5.90	136.3	19.8	2.35
56	V4270	15	Cist	87771	1257	72	66241	26426	109	8483	259	1870	29.4	13.9	107.1	7641	69.8	14.2	2.67	0.83	37.89	39.2	5.90	106.9	16.4	1.57
57	V4271	15	Cist	89730	1377	64	66055	34145	54	10647	617	2337	31.1	12.2	150.8	6753	68.9	13.2	3.55	1.66	37.89	40.0	6.75	105.0	16.4	2.35
58	V4272	15	Cist	77237	1198	68	59005	20160	72	6319	143	1636	25.2	11.4	80.5	6753	60.8	11.2	1.78	0.83	34.59	35.8	5.90	89.0	10.9	1.57
59	V4273	15	Cist	82901	1138	65	59468	31602	64	10560	456	3739	27.7	13.1	139.6	6397	72.4	11.2	2.67	0.83	37.89	39.2	5.90	102.2	14.3	1.57
60	V4274	15	Cist	88248	898	63	65963	33963	59	10301	277	2337	21.0	11.4	146.5	7019	65.3	10.2	1.78	0.83	36.24	36.6	4.22	102.2	13.0	1.57
Ticknall, Church Lane																										
65	V4275	17	Cist	81101	778	59	60675	31330	54	9435	268	2220	21.8	10.6	138.8	6131	65.3	11.2	1.8	0.83	33.8	34.1	4.22	94.6	10.9	1.57
66	V4276	17	Cist	103494	1317	88	48428	22158	206	8137	241	1519	62.1	15.5	60.8	10662	98.4	23.4	4.4	1.66	48.6	51.1	10.12	120.2	21.2	2.35
67	V4277	17	Cist	92006	898	81	71807	17436	132	6232	107	1285	42.8	14.7	54.0	10040	88.5	17.3	5.3	1.66	46.1	49.4	8.43	110.7	23.9	2.35
68	V4278	17	Cist	102276	1138	89	49542	20977	213	7964	215	1636	61.3	15.5	60.8	10928	112.7	24.4	6.2	2.49	51.1	55.4	10.96	120.2	28.0	3.13
69	V4279	17	Cist	104553	1257	89	42676	22249	203	8310	206	1753	68.8	16.3	56.5	10573	86.8	24.4	4.4	1.66	46.1	49.4	9.28	121.1	19.8	2.35
70	V4280	18	MP	114981	719	95	48336	19615	249	6752	152	1519	27.7	18.0	75.4	9063	66.2	14.2	3.6	0.83	41.2	43.5	5.06	151.4	17.7	2.35
71	V4281	18	MP	89730	659	72	48336	16346	203	5886	143	1285	31.1	13.1	61.7	8174	70.7	15.3	3.6	0.83	37.1	39.2	5.90	102.2	16.4	1.57
72	V4282	18	MP	111117	2156	77	67076	32329	123	1523	483	2103	43.6	16.3	90.8	6131	76.0	17.3	3.6	1.66	37.9	40.0	5.90	126.8	17.7	2.35

										5																
73	V4283	18	MP	101906	1377	77	49634	18435	250	6752	197	1519	40.3	14.7	72.8	8263	68.0	17.3	2.7	0.83	39.5	40.9	5.90	122.1	15.0	1.57
74	V4284	18	MP	116623	898	94	69024	19343	250	7444	295	1636	47.0	18.0	73.7	9151	78.7	19.3	3.6	1.66	43.7	46.0	5.90	144.8	21.2	2.35
Sneyd Green																										
K118.76			Roof tile	87083	958	57	42212	11442	48	4328	804	1986	30.2	13.1	46.3	6841	53.7	25.4	1.9	0.75	26.4	19.6	4.47	112.6	10.2	0.78
K118.11			Pot body	123293	1617	80	30616	14802	66	6059	358	1519	47.0	20.4	61.7	8707	82.3	125.2	3.3	1.25	39.5	37.5	9.28	170.3	17.1	1.41
C.S.8			Pot base	119958	1617	79	27183	13622	52	5107	715	1870	31.1	20.4	61.7	8974	76.0	44.8	3.2	1.16	37.1	33.2	7.08	141.0	16.4	1.57
oxide to element factor				**1.889**	**1.399**		**1.43**	**1.205**		**1.658**	**1.291**	**1.348**				**1.668**										

The interpretation of the ICPS pottery data has had to assume that the samples were all dissolved completely, but unfortunately it is possible that isolated examples were not, and that departures from the typical chemistry for a particular group may be an incorrect analysis rather than a real difference in pot clay chemistry. Inspection of Table 3 highlights a number of samples within specific groups which seem to be lower in concentration for these elements compared to the rest of their group: REA12 and REA14 (sample nos 11 and 13) – Wednesbury (Lower High St) Midlands purple; REA26 and REA34 (sample nos 25 and 32) – Burslem (Market Place and School of Art) Cistercian-type; REA47 and REA53 (sample nos 45 and 50) – Nuneaton (Chilvers Coton) Cistercian-type and Midlands purple; and REA60 (sample no. 76) – Austin Friars Leicester Cistercian-type. There are some positive indications, however, that these are relatively limited instances, since for example the long series of analyses of pottery from Austin Friars Leicester (with the above exception) do not show any indications of analyses which differ from their respective group. Also, to anticipate the statistical interpretation of the ICPS data, the Bordesley Abbey pottery did not show similarities to the chemistry of these specific production groups so it has not affected the overall interpretations regarding Bordesley Abbey pottery and may only have affected sample no. 76 from Austin Friars Leicester. It is possible that some of these individual sherds may depart from the normal distribution of their group on the principal components analysis (PCA) plots, but usually it is not possible to interpret such departures archaeologically. This finding does, however, point to the need in such analysis projects to analyse sufficient examples of pottery from within each known pottery group in order that individual analyses (for whatever reason) do not skew the pattern for the whole group.

7.2.3 Interpretation of the ICPS analyses using principal components analysis

Setting up the principal components analysis

Before starting to use multivariate statistics on the ICPS data, initial inspection of the data table by eye, and some simple scatter plots of pairs of elements indicated there were recognisable patterns of chemical differences between pottery groups. Detailed interpretation of the analyses was then carried out with multivariate statistics, which simultaneously considers the concentrations of many elements in each sample. For this investigation, principal components analysis (PCA) was used; descriptions of its application to archaeology are given elsewhere (see for example, Baxter 1994 and 2003; Shennan 1988). The SPSS version 15 statistical package was used for this work (Pellant 2007). For interpreting the PCA plots (Figs 2–7), each individual item analysed has been shown by a symbol for the group/type to which it belongs, though this information has not been used in any way by the statistical computer program. Such PCA plots are effectively chemical ‘maps’ for the items analysed, and we expect that, if the ceramics are made of the same clay within one group, they will plot in the same part of the figure. Further, different groups of items which are similar in ICPS analysis will plot close together or overlap; items or groups which have significant differences in clay chemistry will plot in different parts of the figures. The PCA was carried out in a series of stages, in which items with very different chemistry were removed from the analysis to allow interpretation of those groups of pottery which showed much subtler differences in chemistry.

Principal components analysis was particularly useful for an initial examination of both the AES and MS results. Seventeen of the ICP-AES elements shown in Table 4 were included in the tests, chosen for the reliability of measurement and not subject to post-depositional effects. Some elements tend from past experience to add only ‘noise’ to the interpretation (for example those near their detection limit, and phosphorus can be subject to post-deposition changes). Before carrying out the tests, the results were first converted to logarithms to remove large element-to-element differences in numerical values. PCA looks for the largest variations in concentration of an element across the whole set of samples, so elements showing chemical differences between, in this case, different production centres, are particularly highlighted. If the production sample groups were essentially the same in chemistry of the clay fabric, no systematic differences in their principal components would result. We can display the principal components as axes on a scatter plot (eg Fig 2) where each point represents the composition of a single sample (as on a composition 'map'), with symbols for different sample groups. An idealised principal components plot would show each group of pots from the same pothouse as a cluster of points close together, but in a different part of the figure to all other such groups. Such idealised situations do occur in ceramic provenance studies, but only where there are quite large differences in clay chemistry between the groups, or where there are only a very few groups.

Table 5 presents the significant statistical information on each PCA plot, including the amount of variability ('%variance') captured by each of the first three principal components. The variance signifies the chemical differences between all the pottery included in a specific set of items examined by PCA. Each component 'explains' or 'captures' some of those chemical differences, with the variance decreasing from PC1>3 as more and more variance is 'explained' by each successive component. Interestingly, while the total amount contained in the first three components lies between 74 and 79%, the proportion attributed to each of the three components varies (100% would represent 'total explanation' captured in three components). The next series of columns indicate which elements contribute to the components. Most elements contribute to the first (the 'loadings') but the elements which contribute to PC2 and 3 vary, though many of the same elements crop up frequently. They are listed in descending order of contribution to the component. Thus for example for Figure 2, the second component will have high concentrations of vanadium, titanium etc (in descending significance in the component) towards the top of the figure (all figures have the second component plotted vertically, the horizontal axis is often the third component but occasionally the first). It is interesting that except for dysprosium appearing in Figure 7, the rare earth elements are not the main elements contributing to the components. The main contributing elements include several major elements – calcium, magnesium, aluminium, titanium, manganese and sodium – and several trace elements – chromium, vanadium, scandium and lithium.

Table 5 Summary statistics from the PCA figures, indicating the variance and 'loadings' for each component

		% variance				element loadings on components		
	Fig no	PC1	PC2	PC3	Sum PC1-3	PC1	PC2	PC3
ICPS this project only								
All original data	2	47	20	12	79	Most elements +ve	V .83, Ti .74, Mg -.70, Mn -.70, Ca -.66, Al -.62.	Li .73, Ni .60, Cr.60, Sc -.49, Fe -.49
Removed: Nuneaton and all Leicester except Cistercian	3	51	20	7	79	Most elements +ve	V .80, Al .81, Sc .79, U .72, Na -.61	Cr .78, Ti .43, Mn -.43, Li .42
All Burslem and Wednesbury MP only	4	59	11	6	77	Most elements +ve	Cr .89, Ti .84, Ni .73, V .50, Ca -.49	Li .59, Ca .49, U .45, Sr .45
ICPS this project plus Ticknall and Sneyd Green								
All combined ICPS analyses except Leicester MP	5	46	20	9	75	Most elements +ve	V .72, Ti .70, Ca -.70, Na -.70	Cr .62, Li .50, Sc -.43, Mn -.43
Nuneaton MP and Ticknall MP removed	6	47	21	7	76	Most elements +ve	Sc .81, V .74, Ti .67, Na -.59, Ca -.58	Cr .63, Ti .50, Mn -.47, Li .41
Cistercian only: Wed, Bord, Ticknall, Leicester, Sneyd Green	7	47	15	12	74	Most elements +ve	Ca .85, Mn .69, Mg .68, Ti -.65, Na .51	V .70, Sc .50, Dy .47, Mn .46

Note: the numbers given after each element in the 'loadings' column indicate the contribution that element makes to the component (1 would be the maximum). The elements are listed in descending contribution to the component for that PCA run, and only the highest have been listed. Non-listed elements make significantly less contribution to the component. An element with a positive number would tend to plot pottery with high concentrations of that element towards the positive end of the principal components plots. One with a negative number would tend to plot pottery with high concentrations of that element towards the negative end of the plot.

Principal components analysis on all the items analysed by ICPS for this project

The interrelationships between the ICPS analyses obtained in this project were first examined, and then later a further series of PCA analyses were carried out to compare the present data with two previous sets of ICPS analyses on other production sites. Before undertaking PCA, the selection of elements to include was considered. It was necessary to exclude any elements which might be subject to post-deposition incursion or leaching, ie phosphorus and barium; those which might be present in the glaze, but have migrated into the body fabric, including lead, zinc, and copper; those which might have been introduced during drilling, ie cobalt (present in the drill, where used); and also those which might show poor analytical accuracy, ie erbium and thulium.

This left the following elements for the PCA statistics on all the ICPS analyses carried out for this project: aluminium, magnesium, calcium, strontium, sodium, potassium, rubidium, caesium, chromium, iron, manganese, nickel, lithium, scandium, yttrium, titanium, cerium, dysprosium, europium, gadolinium, holmium, lanthanum, neodymium, praseodymium, samarium, terbium, ytterbium, uranium, thorium and vanadium.

A PCA run on all the 90 samples analysed in this project showed no obvious outliers – that is, items whose analysis was very different indeed to the rest. The first three principal components (PC1–3) contained a total of 79.5% of the chemical variation in the whole dataset (Table 5), and these components can be considered to represent the overall chemistry of the items. Plots of the first three components are thus very fair representations of the chemical composition of each pottery item.

As in many previous ICPS studies on ceramics, the first component is correlated almost entirely with 'total elements' – the '% temper' factor, such as most of the major and trace elements present in the clay (as against the percentage of diluting temper such as quartz). It indicates the percentage of diluting temper (natural or added, probably quartz in some form) in the ceramics.

Figure 2 shows the plot of the resulting second and third principal components for all 90 sherds – ceramics with higher vanadium, uranium, titanium and aluminium and lower sodium, manganese, magnesium and calcium (in descending amount of contribution to the second component) will tend towards the bottom of the figure. Elements separating the ceramics in the horizontal axis (the third component PC3) are higher lithium, nickel, chromium, caesium and strontium and lower iron, scandium and ytterbium towards the right hand side.

The Midlands purple from Wednesbury Lower High St and Market Place have higher concentrations of aluminium than the Wednesbury Cistercian-type wares, and most are also higher in iron but lower in sodium and potassium. They are generally very much higher in the trace element scandium, which tends to be geochemically associated with aluminium in the clay minerals so is not unexpected. Rubidium is lower in the Midlands purple from Lower High St compared to Market Place, so the two groups may be distinguishable on this and perhaps other elements. Two Midlands purple sherds in group 3 (sample nos 10 and 12) have low rare earth levels and low aluminium, potassium, scandium and other elements compared to the rest. The Midlands purple from Wednesbury also share very high scandium levels with the pottery from Burslem. The Wednesbury Cistercian-type wares from both Lower High St and Market Place are distinguished by their high calcium content and high level of potassium and magnesium.

It is notable that all the Bordesley Abbey 'test' pottery items are on a diagonal from top left to mid bottom of this figure (Fig 2), mixed in with ceramics from Wednesbury, as well as two Austin Friars Leicester Cistercian-type wares (sample nos 75 and 77). This indicates that they all have quite similar chemistry to each other, but differ in clay chemistry from all those items of pottery which fall into the mid and upper half of this figure. Those sites whose ceramics lie in this latter region away from the Bordesley Abbey pottery include all the items analysed from the production centres of Burslem and Nuneaton, and all the Austin Friars Leicester samples with the exception of the two sherds of Cistercian-type ware from Leicester (discussed below). On this figure, the Austin Friars Leicester Midlands purple all plot in the top right. However, overlapping with the Bordesley Abbey pottery in the lower half of the figure are all the Cistercian-type pottery sherds analysed from the Wednesbury Lower High Street site and two from the Town centre site. The calcium content of the Wednesbury Cistercian-type wares from both Lower High St and Market Place, and of a number of the Bordesley Abbey sherds, is in the range 1500–2500 ppm and is significantly higher than almost all other pottery in the project. These groups look quite consistent in analysis across almost all elements – they also share the same distinctively high level of potassium and magnesium which is a unique feature of the Wednesbury Cistercian-type pottery, and indicates that Wednesbury items are present among the Bordesley items.

[NB on Figs 2–7 Nuneaton Bermuda Road = 11 Bermuda Road (NB 99) and Nuneaton Chil C Scott = 16–22 Bermuda Road (NCC 79).]

Principal components analysis was then run a second time after removing all the Austin Friars Leicester Midlands purple sherds, but leaving in the Austin Friars Leicester Cistercian-type pottery. The resulting plots of the first three components showed that all the Nuneaton sherds are quite different to any of the Bordesley Abbey sherds, so none of the Bordesley items have the characteristic chemistry of the Nuneaton production centre.

This difference then prompted **a third run of PCA** this time omitting the Nuneaton sherds as well, and the resulting pairs of plots of the first three components were then used as a definitive interpretation of the ICPS data. The plot of the first and second components is shown in Figure 3 and seemed clearer than the plot of second and third components. Compared to previous PCA analyses the third component contributes a smaller percentage to the variation (information) in the overall ICPS analyses – see Table 5. The figure seems to show the distribution of items into three broad spreads, lying diagonally above each other on the plot. These have been designated PCA groups A to C (reading from the top), and the items included in each group are shown in Table 6. The diagonal spread is explicable as the differences in the amount of diluting temper present in pottery from the same sub-group. The first component is mainly correlated with the concentrations of all the elements (as for the first PCA described above). Sherds with lower amounts of temper lie towards the right of the figure. The second (vertical) component is also associated with the concentrations of a number of chemical elements, so the less temper is present in a sherd made at one production site, the further it will be plotted in a diagonally ascending line across the figure. Dividing the items up in this way into three spreads/groups is a matter of judgement where one draws lines between groups.

Pottery group	Proportion of group	Sample list numbers
PCA Group A (Fig 3)		
Burslem Cistercian and MP	all	21–40 (35 is a waster)
Wednesbury Market Place MP	all	16–18
Wednesbury Lower High St service trenches MP	all	11–15 (11 and 15 are wasters)
PCA Group B		
Wednesbury Town Centre Cistercian	2/5	6 and 7
Bordesley group 24	1/1	94
Bordesley group 25	2/2	95, 96
Bordesley group 28	5/6	105–107 and 109
Leicester Austin Friars Cistercian	3/5	76, 78 and 79

PCA Group C		
Wednesbury Town Centre Cistercian	3/5	8, 9 and 10 (9 is a waster)
Wednesbury Lower High St Cistercian	all	1–5
Bordesley group 26	all	97–101
Bordesley group 27	2/2	102–103
Bordesley group 28	1/6	108
Leicester Austin Friars Cistercian	2/5	75 and 77

Notes to table

A further PCA on the pottery of group A alone showed the Burslem and Wednesbury pottery was chemically similar to each other but could be distinguished. Wasters were present in the analysis from each site. In the follow-up PCA series on the combined ICPS data from this project and pottery from Ticknall and Sneyd Green, it was shown that the three sherds of Cistercian ware from Leicester in group B above were very probably Ticknall products. The two Leicester Cistercian-type assigned to group C still however appear to belong to this chemical group.

Table 6 Association of pottery samples (except the Nuneaton pottery, and Austin Friars Leicester Midlands purple pottery) into three chemical groups using principal components analysis of the ICPS data (see Fig 3)

All the Burslem sherds plot in the top of Figure 3, together with all the Wednesbury Midlands purple apart from one from Meeting Street (no. 20); subsequent examination of sample no. 20 indicated it was actually glazed, rather than exhibiting just a high-temperature sheen, suggesting it should be reclassified as Cistercian-type ware (pers comm, D Hurst). This overlap was investigated further (see below). However, none of the rest of the Wednesbury pottery plots within this group A distribution. It is then fairly apparent that there are differences in chemistry between sherds from some of the production centres which lie towards the top of the figure – for example Burslem – and the Bordesley Abbey items which lie in the lower part of this figure. It seems fairly clear from this figure that there is overlap between the Wednesbury Cistercian-type wares and the Bordesley Abbey items. The Austin Friars Leicester Cistercian-type pottery falls within the two lower spreads of pottery in the figure (ie groups B and C). We can conclude that none of the Bordesley Abbey Cistercian-type ware or the Austin Friars Leicester Cistercian-type ware was made at Burslem nor at Nuneaton, each of which production centres have been found to have different chemistry to the Bordesley Abbey and Austin Friars Leicester items.

Burslem pottery appears generally to have significantly lower concentrations of lanthanum and cerium (two of the rare earth elements) compared to the Nuneaton pottery. The Nuneaton pottery also has higher levels of chromium compared to the rest of the pottery, except the Midlands purple but not the Cistercian-type ware from Austin Friars Leicester, and this would be a distinguishing feature.

All except three of the sherds from Austin Friars Leicester have much higher caesium values (an alkali) compared to the rest of the pottery in the project (the exceptions are sample nos 75 and 77 – Cistercian-type, and 93 – Midlands purple). Its chromium content is another distinctive feature. As a group, Austin Friars Leicester looks very consistent having very similar analyses across most elements for the whole group, and it seems likely also to be quite distinctive compared to the rest of the pottery in chemical analysis. The Austin Friars Leicester Midlands purple has much higher lithium than the Cistercian-type from the same site, and is unique in the total set of pottery analysed, so a useful distinguishing feature. Only two of the 19 (Cistercian-type) sherds from the production centre of Ticknall had similar levels (see below).

On Figure 2, the Nuneaton and Austin Friars Leicester Midlands purple are separate but appear in the top right of the figure. The chemical similarity of the groups, with minor differences, suggest that the source of the Austin Friars Leicester Midlands purple could be from a production centre on similar geology to Nuneaton.

In support of the conclusion about the Bordesley Abbey Cistercian-type samples, negatively none of the items have the same high level of chromium as Nuneaton pottery or the Austin Friars Leicester Midlands purple. However, the Austin Friars Cistercian-type contains lower levels of chromium than the Midlands purple from the same site, and is comparable in level to most of the Bordesley Abbey pottery. It was therefore prudent to await the results of further multivariate statistics before ruling out Austin Friars Leicester as sharing a source with some Bordesley Abbey items.

The mixing of Wednesbury pottery and both Bordesley Abbey and Austin Friars Leicester Cistercian-type ware in PCA groups B and C could suggest production at Wednesbury, apparently for all the Bordesley Abbey and Austin Friars Leicester Cistercian-type ware. However, the fact that there are two distinct groups B and C could be seen as indicating that they are not both from Wednesbury. One might represent Wednesbury (rather as the Burslem pottery is spread across PCA group A) and the other a more distant but as yet unidentified site – it is not one of the other production centres analysed in this project (Ticknall seems to be different again – see below, Table 7). It is significant that group C contains a Cistercian-type ware waster from Wednesbury Town centre (no. 9) which strengthens the case that group C represents a Wednesbury production centre. To anticipate the conclusion of the comparison between the items analysed in this project and comparison sherds from the production centres at Ticknall and Sneyd Green (below), it is not definite that PCA group B is also a Wednesbury production centre, and it may be an as yet unidentified production site. Alternatively group B could represent a different clay source used at Wednesbury, or adjacent West Bromwich (south Staffs, now Sandwell West Midlands) production which has been claimed but not clearly demonstrated in terms of quantity of archaeological material. Shropshire has also been reported to be a producer. Although group B contains three Austin Friars Leicester Cistercian-type wares (sample nos 76, 78, 79), this may be a less likely possibility. Subsequent statistical work (see below) indicated these three to be associated with Cistercian-type ware from Ticknall Peat's Close. That some of the PCA group B pottery comes from Wednesbury is suggested by other manufacturing characteristics observed on these sherds, ie parallel striations on the underside (pers comm, D Hurst; see Section 7.4.1.)

One unexpected feature of this PCA was the mixing of Burslem (Cist and MP) and Wednesbury (MP) pottery in PCA group A. It was suspected to be an artefact of the inclusion of so many different chemical groups within the PCA runs shown in Figures 2–3. Even in those instances (particularly in Fig 3) the Wednesbury Midlands purple was close to but not mixed in to any degree with the Burslem sherds but appears as a thin line of points parallel to the Burslem distribution.

A further principal components analysis was carried out including only all Burslem pottery and Wednesbury Midlands purple, and the plot of the first two components is shown in Figure 4. There is complete separation between the Burslem sherds and the Wednesbury Midlands purple. It is significant that there are wasters from both production centres present within the respective distributions on the PCA plot (sample nos 11 and 15 – Midlands purple from Wednesbury Lower High Street, and sample no. 35 – Cistercian-type from Burslem School of Art). The Midlands purple sample (no. 19) from Meeting Street is mixed in with the Lower High Street group on Figure 4; however, on a plot of PC2 versus PC3 (not illustrated), it is slightly separate, so it is legitimate to say that the sherd from Meeting Street seems to have a slightly different composition to the Lower High Street group and the Market Place group (see above, Fig 2). The ICPS analysis confirms that all the pottery items in Figure 4 represent products of each centre.

Comparison between the ICPS analyses obtained in this project and previous ICPS analyses of pottery from Ticknall and Sneyd Green

Two relevant datasets were identified. The first was a report on characterisation of late medieval/transitional pottery from the production centre of Ticknall, Derbyshire, by ICPS (19 samples: Vince, 2004) and the second a study comprising ICPS analyses of medieval tiles from Hulton Abbey (Staffs) which included three reference ceramics from the white ware production site at Sneyd Green, near Stoke (Hughes 2004). The Ticknall data were shown by the application of factor analysis to the ICPS results to fall into different composition groups, but with a group of Cistercian-type wares from Peat's Close being rather distinct from the rest of the Ticknall samples analysed from the same site and from the Church Lane site. The Hulton Abbey report showed that some of the tiles found at Hulton were consistent in ICPS analysis with reference ceramics from Sneyd Green. Both these datasets had been obtained by ICP-AES analysis (ie not including ICP-MS data) by Dr Nicholas Walsh, Department of Earth Sciences, Royal Holloway, University of London.

To compare against the ICPS results obtained in the present study, the Royal Holloway data needed to be made consistent with that produced at Reading. In addition, because only ICP-AES was used for the Royal Holloway analyses, the ICP-MS elements would need to be deleted from the Reading dataset, so a 'reduced-elements' PCA would be used for the comparison of datasets. The calculations carried out and the resulting corrected ICPS analyses are given in Table 4. The Royal Holloway data were originally expressed as the oxides for the major elements, so they were divided by the element to oxide conversion factors listed in the bottom row of the Table. The major elements also needed converting from weight percent to parts per million (by multiplying by 10,000). In addition, it was necessary to try to obtain inter-laboratory standardisation factors for all the elements analysed in common by both laboratories. Analyses obtained by different laboratories may differ because they are carried out on different machines and using different calibration techniques. To obtain an estimate of these factors, a comparison was made on analyses by each laboratory on multiple samples of a Certified Reference Material (CRM), a Brick Clay (NBS679 – see above) included without identification as such within the batches sent for analysis. The data on NBS679 from Royal Holloway have been obtained over a more than 10-year period (20 analyses). The average results by both laboratories are given in Table 4, and the calculated ratio Reading/Royal Holloway is shown for each element; for practically all elements it is significantly different to 1 so the application of these inter-laboratory adjustment factors was essential. The ratio for each element was used to multiply the original Ticknall and Sneyd Green analyses to be equivalent to the Reading ICPS results.

The list of 22 'reduced elements' PCA analyses on the combined ICPS analyses included: aluminium, magnesium, calcium, strontium, sodium, potassium, chromium, iron, manganese, nickel, lithium, scandium, yttrium, titanium, cerium, dysprosium, europium, lanthanum, neodymium, samarium, ytterbium, and vanadium.

A PCA analysis on the comparison results combined with all pottery analysed in the present project showed there was a separation on the principal components plots between the Ticknall and Sneyd Green pottery and the Bordesley Abbey sherds, with some exceptions. One roof tile from Sneyd Green plotted amongst the Bordesley Abbey sherds, but in the original report on the ICPS analyses (Hughes 2004, 100) it was also outside the spread of the Sneyd-attributed tiles. More unexpectedly, the Cistercian-type ware from Peat's Close also plotted near to the Bordesley Abbey pottery. The Austin Friars Leicester Midlands purple sherds were again distinct from the rest of the dataset in the all-samples PCA. They fell into clusters of sherds by sample group, indicating that each of the Austin Friars Leicester Midlands purple tends to be slightly different from each other though with some chemical overlap between the Austin Friars groups 20–22 (sample nos 80–84, 85–89, 90–92). The singleton Austin Friars Leicester group 23 sherd (sample no. 93) was chemically slightly different to the rest of the pottery analysed in this project, but apparently related to the other Austin Friars Leicester Midlands purple (see also above).

A second PCA was then carried out after removing all the analyses for the Austin Friars Leicester Midlands purple sherds and the resulting plot is shown in Figure 5. The Ticknall Peat's Close Cistercian-type ware is distributed in the middle of the plot, away from the rest of the Ticknall pottery which is in the top right of the figure, between the Burslem and Nuneaton pottery, which itself was on the top right edge of the distribution in the figure. This indicates that the Ticknall pottery, apart from the Cistercian-type from Peat's Close is all made from very similar clays, but the Peat's Close Cistercian-type has been made from a distinctive clay unlike the others from Ticknall.

A third PCA was carried out after removing all Nuneaton sherds, and the Ticknall Midlands purple from both sites and all except one of the Cistercian-type from Church Lane but leaving in the Peat's Close Cistercian-type and the Sneyd Green analyses. The resulting plot of the second and third components is shown in Figure 6 and this and the plot of the first two components showed that the Burslem sherds formed a distinctly separate and coherent group running diagonally across from the lower left to top right of the figure, with no clear separation between the Burslem Midlands purple and Cistercian-type from either the Market Place or School of Art. The Burslem ceramics of these two types appear to have a relatively homogeneous and distinctive clay composition, indicating the use of the same clays for both types and at both find sites. However, the Midlands purple sherds from Wednesbury Lower High Street, Market Place and one (sample no. 19) of the two from Meeting Street appear to have rather similar chemistry to the Burslem pottery. The two pottery samples analysed from Sneyd Green plotted close to each other and a short distance outside the spread of the Burslem sherds. Given that Sneyd Green is close to the centre of Stoke, the similarity in clay chemistry is entirely consistent with expectations.

The unexpected finding from this series of PCA analyses, however, is that the Peat's Close Cistercian-type from Ticknall has a rather different chemistry to the rest of the Ticknall pottery. The difference is greater than that found among the other production centres of Burslem and Nuneaton. Vince (2004) had found using factor analysis that the Peat's Close Cistercian-type had a different chemistry to the rest of the Ticknall sherds analysed. The Peat's Close Cistercian-type shares similar clay chemistry to one Cistercian-type sherd from Church Lane (no. 65) and falls into the same part of the PCA plots as the PCA group B selection identified in the earlier series of PCA analyses. This finding was explored further to resolve the problem.

Since the presence of the Burslem chemical groups may have distorted the relationship between the rest of the pottery on these PCA plots, a further run of PCA was made, this time omitting in addition all the Burslem pottery and the Wednesbury Midlands purple, which had plotted close to the Burslem sherds, and are grouped together in PCA group A. The resulting plot for the second and third principal components is shown in Figure 7. The selection of only chemically quite similar material for this principal components run has allowed a more accurate picture to emerge of the relationships between these ceramics. This caused small changes, discussed below, to the groupings seen in Table 6 which represents an intermediate stage in the analytical argument. Table 7 summarises the final conclusions based upon this PCA, superseding Table 6, and adding the Ticknall samples.

The Ticknall samples split into two chemical groups, designated Ticknall 1 and 2 (Table 7). Ticknall 2 includes all the Ticknall Midlands purple (Peat's Close and Church Lane) and four out of five Church Lane Cistercian-type samples. Ticknall 1 includes all the Peat's Close Cistercian-type and the single remaining Cistercian-type sample from Church Lane (sample no. 65). Ticknall 1 is positioned on the lower left of Figure 7 and in the centre of Figure 5, while Ticknall 2 is in the upper right of Figure 5. Ticknall 1 thus shares chemical similarities with some other Midlands production sites (eg Wednesbury, Sneyd Green), but, on Figure 7, Ticknall 1 is distinct from PCA group C (Wednesbury) and PCA group B (source unknown, but possibly also Wednesbury; see above, this section).

The separation of Ticknall 1 and 2 could be theoretically explained in several ways. A possible explanation would be that Ticknall 1 was produced elsewhere, but the identification of at least one waster amongst both groups (Table 7) suggests neither was imported and so both represent local production. An alternative explanation for the difference between Ticknall 1 and 2 is that they represent quite different clay types, and clay types local to Ticknall. A further possible factor might be that the two chemical groups represent different chronological periods of production. The Church Lane samples derive from pottery – the vast majority Midlands purple and mostly Midlands purple forms used as saggars – from the infill of a kiln which was excavated in 2006 (Boyle and Rowlandson 2006–8). The Peat's Close samples were collected during a decade of fieldwalking; kiln props, wasters and saggars were recovered from this site (Boyle 2002–3; Spavold and Brown 2005). The identification of one Church Lane sample (no. 65) as part of the Peat's Close Cistercian-type Ticknall 1 group could suggest some cross-contamination of the excavated Church Lane assemblage with material from other Ticknall production sites (Boyle and Rowlandson 2006–8, 58); the two sites are physically quite close together and it is not impossible that sherds could move between the two (eg pots made at one place fired at another).

Pottery group	Proportion of group	Sample list numbers
PCA Group B: origin unknown		
Wednesbury Town Centre Cistercian	2/5	6 and 7
Bordesley group 24	1/1	94
Bordesley group 25	2/2	95, (96* – ambiguous)
Bordesley group 28	4/6	104, 106, 107 and 109
PCA Group C: origin probably Wednesbury		
Wednesbury Town Centre Cistercian	3/5	8, 9 and 10 (9 is a waster)
Wednesbury Lower High St Cistercian	all	1–5
Bordesley group 26	4/5	97–100
Bordesley group 27	2/2	102–103
Bordesley group 28	2/6	105 and 108
Leicester Austin Friars Cistercian	2/5	75 and 77
Ticknall 1 (Cistercian from Peat's Close and one Church Lane)		
Leicester Austin Friars Cistercian	3/5	76, 78 and 79
Bordesley group 26	1/6	101
Ticknall Peat's Close Cistercian	all	56–60 (56 and 60 are wasters)
Ticknall Church Lane Cistercian	1/5	65
Ticknall 2 (rest of samples)		
Ticknall Church Lane Cistercian	4/5	66–69 (68 is a waster)
Ticknall Church Lane Midlands Purple	5/5	70–74
Ticknall Peat's Close Midlands Purple	4/4	61–64 (61 is a waster)
Source unknown, but of similar geology to Chilvers Coton, Nuneaton		
Leicester Austin Friars Midlands Purple	all (groups 20–23)	
Notes to table The distribution of samples between PCA groups B and C and Ticknall 1 shown here is based on the principal components analysis of Figure 7. The clay chemistry of the two Ticknall groups 1 and 2 in this table are significantly different from each other. The assignment of Bordesley Cistercian sample 96 (see PCA group B above) is difficult – it appears between PCA groups B and C on Figure 7, so its origin is not clear.		

Table 7 Summary of final conclusions about the origins of pottery samples from the consumer sites of Bordesley and Austin Friars Leicester, revising some of the groups shown in Table 6

On this PCA run, the Ticknall Peat's Close Cistercian-type and the Church Lane Cistercian-type single sherd plotted in the bottom left of the figure (Fig 7), away from both the Wednesbury and the Bordesley Abbey items, apart from one Bordesley group 26 item (sample no. 101) which now appears to be a Ticknall Cistercian-type ware, probably from the Peat's Close production in Ticknall group 1 (Table 7; see above). In addition, the new PCA showed that three of the Austin Friars Leicester Cistercian-type sherds (sample nos 76, 78 and 79) now fell within the Peat's Close pottery group Ticknall 1 and are, therefore, most likely to be Ticknall products. The present ICPS study has established the presence of Ticknall Cistercian-type products at Austin Friars Leicester and Bordesley Abbey. Cistercian-type ware that appears typologically (form and decoration) identical to material collected from Peat's Close has previously been identified at Austin Friars Leicester in phase 9A, associated with Church Lane style Midlands purple ware (Boyle 2002–3, 116; Boyle and Rowlandson 2006–8, 58; see below, Section 8).

In the same plot, however, the remaining two Cistercian-type sherds from Austin Friars Leicester (sample nos 75 and 77) plotted at the top of the figure among the Wednesbury Lower High Street Cistercian-type and four (sample nos 97–100) of the five Bordesley group 26 sherds (nos 97–101), which chemically belong to the production centre identified as PCA group C (likely to be Wednesbury products).

One Bordesley Abbey group 28 sherd (no. 105) is now assigned to PCA group C (probably Wednesbury production). The group of sherds which constitute PCA group B (origin unknown but also possibly Wednesbury) includes some of the same sherds as in Table 6, namely two of Wednesbury Town centre Cistercian-type (sample nos 6 and 7), and out of the Bordesley Abbey Cistercian-type, the single sherd of group 24 (no. 94), both of group 25 (nos 95, 96) and now four (104, 106, 107, 109) of the six in group 28 (nos 104–109). One of the Bordesley Abbey group 25 sherds (no. 96) falls between PCA groups B and C on Figure 7 so it is difficult to decide to which of them it should be assigned; however, if both PCA groups B and C are in fact from Wednesbury, then this could be overplaying the differences and be a reflection of different production sites not different production centres.

Comparison of interpretation of the two sets of PCA analyses

The first series of PCA analyses (Figs 2–4) included the ICPS data obtained in the present study. Its advantage is that a full set of chemical elements analysed by both AES and MS can be used in the tests. All the analyses were obtained by the same laboratory so we can be confident that slight differences in chemical analysis between say two items are real. On the other hand, PCA of the combined dataset (Figs 5–7) had to use a 'reduced elements' dataset, omitting the MS elements which may have been crucial, for example the distinctly high caesium content of the Austin Friars Leicester pottery. Additionally, it was necessary to calculate inter-laboratory standardisation factors to bring the whole dataset onto the equivalent analysis basis. Far more repeat analyses of the NBS679 standard were available from the Royal Holloway laboratory (20) than the four analysed at Reading, so the calculation of the inter-laboratory ratio itself has errors higher than we would wish. The comparison datasets have added further examples of pottery (Ticknall) which seem to share similar chemistry with some of the Bordesley Abbey and Austin Friars Leicester sherds, and such additional information is valid and widens the picture of the production and distribution of Cistercian-type and Midlands purple in this region. Balancing this extra information against the reduced number of elements on which the combined data PCA is based, it has been judged best to use the statistics for the combined data to draw final conclusions (Table 7) about the detailed interpretation of inter-sample relationships between the production centres and their constituent production sites, and with the Bordesley Abbey and Austin Friars Leicester consumer items.

Comparing the results of the PCA analyses of the original ICPS data alone, and the combined set of ICPS data, almost the same groups of sherds fall into the chemically-distinguishable groups PCA B and C, though there are slight differences. Also the introduction of the Ticknall ICPS results has now assigned one Bordesley Abbey (no. 101) and three Austin Friars Leicester (nos 76, 78, 79) Cistercian-type wares to Ticknall Peat's Close.

7.2.4 **Conclusions**

This investigation has through ICPS analysis characterised a number of west Midlands production centres and has thrown light on both the relationships between the various production centres and on the movement of ceramics within the west Midlands at this period by assigning the Cistercian-type ware pottery analysed from Bordesley Abbey and Austin Friars Leicester to its probable place of production.

In the detailed summaries of each production centre and consumption site which follow, the final conclusions of the series of principal component analyses, given in Table 7, are incorporated.

Production centres

Nuneaton

The pottery was chemically distinct from all other pottery analysed in the present study so no other pottery analysed in the project was assigned to production there, and none of the Nuneaton sherds were inconsistent with the chemical signature for the centre. There were slight chemical differences among the pottery from the centre however – see Figure 5 which shows slight differences between the clays used for the Cistercian-type and Midlands purple. A significant proportion of the analysed samples from Nuneaton were wasters, which ICPS analysis has confirmed as local products: nos 41, 43, 44, 46, 48–54.

Burslem

This centre's products showed a coherent chemical pattern, distinct from other centres though showing chemical similarities to Midlands purple from Wednesbury. The Burslem Cistercian-type has a slightly different clay chemistry to the Midlands purple (cf Fig 4).

Wednesbury

The ICPS analyses from this centre are complicated. The Midlands purple has a coherent clay chemistry, different to the clay used for the Cistercian-type from Wednesbury, and also distinguishable from pottery made at Burslem, with which, however, it does show some chemical similarities. This is probably due to using the same geological type of clay locally available at each site. The Midlands purple from two Wednesbury sites (Lower High Street and Market Place) also appear to be distinguishable from each other – they are not made of identical clays and may represent different kilns or chronological periods of production. The single sherd from Wednesbury Meeting Street (no. 19) is also distinguishable from the other two sites on the second and third principal components (not illustrated). The Cistercian-type ware from Wednesbury falls into two clay chemical groups. One contains a waster (PCA group C) and is very probably Wednesbury, but the other chemical group (represented by PCA group B) may on the basis of the ICPS analysis alone be either another production at Wednesbury or elsewhere (West Bromwich and Shropshire would be possible candidates).

Ticknall

As Vince (2004) has already shown, the pottery from Ticknall falls into different chemical groups. The Midlands purple from Ticknall and the Cistercian-type ware from the Church Lane site (apart from one sherd) are chemically fairly similar to each other and distinguishable from other production centres. They form chemical group Ticknall 2 (Table 7). The Cistercian-type ware from the Peat's Close site – including a waster – and one sherd from the Church Lane site show a rather different clay chemistry, with similarities to , but distinguishable from PCA groups B and C, and form the group Ticknall 1. Three Cistercian-type sherds from Austin Friars Leicester and one Bordesley Abbey Cistercian-type sherd (group 26, no. 101) belong to this chemical group.

Sneyd Green

Two Midlands white ware pottery items from this production site have similar chemistry to the Burslem pottery but are chemically slightly different. This would be consistent with the close proximity of Sneyd Green to the centre of Stoke.

Summary

Summarising the implications of the ICPS analyses from these production centres, the frequent use of different clays for the Midlands purple and Cistercian-type wares is noted. It is nonetheless true that between-centre chemical differences are significantly greater than the within-centre chemical differences, even between these two types of pottery. It has, therefore, been possible to chemically distinguish by ICPS the products of each of the production centres studied, and to assign each of the Bordesley Abbey and Austin Friars Leicester Cistercian-type ware vessels to one or other of the centres – there are no Bordesley or Leicester items whose chemistry suggests production at a site apart from those studied. One question not entirely resolved by the ICPS analysis alone is where the PCA group B pottery was made. If sherds from other possible Midlands production sites become available in future, such as West Bromwich or Shropshire, or a previously unsuspected site, chemical analysis by ICPS could characterise and rule out these other potential production centres. The other remaining question concerns the Ticknall 1 group which consists of the Peat's Close Cistercian-type, one Church Lane Cistercian-type, three Cistercian-type from Austin Friars Leicester and one Cistercian-type sample from Bordesley Abbey (from group 26). Chemically Ticknall 1 is distinct from Ticknall 2 (assumed to be local products due to the presence of a kiln) and shares chemical similarities with other Midlands production centres, but the identification of wasters suggests local production again.

Consumer sites test case

Bordesley Abbey

Comparison of the chosen examples of Bordesley Cistercian-type ware with the ICPS analyses of the production centres shows that a series of Bordesley items are Wednesbury products, falling within PCA group C: four out of five of group 26 (sample nos 97–100), both of group 27 (nos 102, 103), and two of group 28 (nos 105, 108) (Table 7). The rest of the Bordesley pottery apart from one item falls within PCA group B whose origin is not entirely clear (see the discussion above under Wednesbury): the single example of group 24 analysed (no. 94), both of group 25 (no. 95; between B and C, no. 96), and four (nos 104, 106, 107, 109) of the six examples from group 28. The other sherd from group 26 (no. 101) seems to be a Ticknall Peat's Close product.

Austin Friars Leicester

The Midlands purple from this site is chemically different from any other pottery analysed in this project. The four different groups (20–23; nos 80–93) selected for analysis seem to represent slightly different clay compositions, so may represent different kilns or chronological periods of production. There are similarities between the chemistry of the Austin Friars Leicester Midlands purple and the Nuneaton production centre, though they are not identical, suggesting a source for the Austin Friars Midlands purple on similar geology to Nuneaton. Three of the Austin Friars Cistercian-type wares are very probably Ticknall (Peat's Close) products and the other two fall within PCA group C which appears to represent production at Wednesbury.

7.3 Petrographic study (*by* R A Ixer)

For the detailed methods and technical petrographic study reports see Appendix 4.

In this section, where appropriate, brief comments are made comparing specific material with the rest of the samples. A further discussion and conclusions are also included below. Summaries of select petrographic characteristics are given in Table 8 for the Cistercian-type wares and in Table 9 for the Midlands purple wares.

7.3.1 Synoptic results for the Cistercian-type wares

Production centres: Wednesbury

There is very little of distinction petrographically in these pots. They have fabrics comprising monocrystalline quartz with minor to trace amounts of potassium feldspar and plagioclase and less frequently mica. Rock fragments are less abundant than quartz and comprise meta-sandstone/quartzite, sedimentary chert plus sandstones (9-2), stretched quartz (4-1 and 5-1) and vein quartz (1-1 and 5-1). 'Exotic' rocks are very rare but include phyllite (1-1), volcanics (9-2) and ?rhyolite (10-2).

Wednesbury sits on Coal Measure sediments including fireclays and the local drift comprises Boulder Clay and sands and gravels. Due to the absence of anything diagnostic or unusual it is almost impossible to provenance the raw materials used in the manufacture of these pots. Any clean silty clay (or combined clean sand and clean clay) from the above geological formations would be suitable.

Comparison with other sites

Although Cistercian-type samples from Austin Friars Leicester are petrographically similar to Wednesbury most of those from Bordesley Abbey are not, suggesting that pots manufactured at Wednesbury may be rare amongst those found at Bordesley.

Production centres: Burslem

There is very little of distinction petrographically in these pots (although 21-6 is an unusual pot), and generally the pots from Burslem have more disparate fabrics than those from Wednesbury. Burslem fabrics comprise monocrystalline quartz with minor to trace amounts of potassium feldspar and plagioclase and less frequently mica. Rock fragments are less abundant than monocrystalline quartz (other than in 32-8 where equal numbers of single grains and rock clasts occur) and comprise meta-sandstone/quartzite, sedimentary chert plus stretched quartz (31-8) and vein quartz (21-6 and 32-8). 'Exotic' rocks include very rare, fine-grained volcanics (32-8 and ?31-8).

Burslem sits on the Coal Measures with abundant clays/mudstones but in the absence of anything diagnostic or unusual it is almost impossible to provenance the raw materials used in the manufacture of these pots more precisely. Any combined clean sand and clean clay, or silty clay would be suitable.

Comparison with other sites

Although Cistercian-type samples from Austin Friars Leicester are petrographically similar to Burslem those from Bordesley Abbey are not suggesting that pots manufactured at Burslem are not amongst those found at Bordesley.

Production centres: Ticknall

The two types of pottery carry rare, monocrystalline quartz accompanied by trace amounts of potassium feldspar. Rock clasts comprise sandstone and chert and meta-sandstone/quartzite and quartz mosaics (sample 56-15). 'Exotic' rocks are absent to extremely rare but include ?tuff (sample 68-17).

Macroscopically Ticknall Cistercian-type and Midlands purple wares can be distinguished from each other on grain size. Although Vince (2007) suggests that at Ticknall Cistercian-type and Midlands purple pots were manufactured from different clays, the extremely limited data (four pots) in this study do not confirm this but suggest very similar raw materials were used.

Ticknall potting clays are believed to derive from the local Coal Measures (Boyle 2002–3) and the petrography of the Ticknall Cistercian-type pots is consistent with that but due to the absence of anything diagnostic or unusual, any other clean, silty clay (or combined clean clay and clean sand) would be suitable.

Comparison with other sites

Although Cistercian-type samples from Austin Friars Leicester are petrographically similar to Ticknall products those from Bordesley Abbey are not suggesting that pots manufactured at Ticknall are not amongst those found at Bordesley.

Production centres: Nuneaton

Both types of pottery are similar to each other and carry monocrystalline quartz with ?syntaxial quartz overgrowths accompanied by trace amounts of potassium feldspar and plagioclase. Rock clasts are fewer in number than single grains but include meta-sandstone/quartzite, sandstone and quartz mosaics but not chert. 'Exotic' clasts include fine-grained feldspathic igneous rocks and phyllite.

Williams (1984, 197) petrographically described 'fabric E' (Cistercian Ware) from Chilvers Coton as having much, 0.05–0.2mm diameter quartz with rarer, larger quartz grains, mica, quartzite and iron ore, a description that does not conflict with the present ones.

Nuneaton sits at, or close to, the junction between the Middle and Upper Coal Measures and Triassic rocks, the Mercian Mudstones. In addition a series of very old (Pre-Cambrian and Cambrian) igneous rocks, quartzites and fine-grained meta-sediments lies within a kilometre or so, as do Recent alluvial deposits. There are subtle differences between Nuneaton, and the Wednesbury, Burslem and Ticknall non-plastics, namely the lack of sedimentary chert and the increase in amounts of phyllite and feldspathic rocks in the Nuneaton pots.

Comparison with other sites

Cistercian-type samples from Austin Friars Leicester are petrographically dissimilar to Nuneaton but many of those from Bordesley Abbey share characteristics with the sampled material from Nuneaton.

Consumer sites: Leicester

The fine-grained nature of the Cistercian-type ware fabrics and their small number (3) makes any discussion difficult. Sherd 75-19 is an oddity in having much unusual ?adventitious matter introduced during the manufacture of the slide.

All three have monocrystalline quartz accompanied by minor amounts of potassium feldspar and phyllosilicates (muscovite and rare biotite). Rock clasts are far rarer than quartz and comprise meta-sandstone/quartzite, sedimentary chert and sandstones.

However, 79-19 differs from the other two in having a greater number of rock clasts, these are mainly fine-grained sandstones. In this it shares a few similarities with Burslem pots 22-6, 31-8 and 32-8 and both Ticknall pots (especially sample 56-15) but is very different from other Burslem pots for example 21-6.

Comparison with other sites

Leicester 75-19 and 77-19 samples are less distinctive but are similar to fine wares from Wednesbury and Ticknall, dissimilar to Burslem wares and unlike Nuneaton Cistercian-type wares.

Consumer sites: Bordesley Abbey

At least two main populations may be present, as follows

i. Cistercian-type pots 95-25, 96-25, 101-26, 103-27 and 104-28 carry significant amounts of 'exotic' rock clasts in addition to meta-sandstone, sandstone, chert and single quartz and feldspar grains. Three carry tuff/fine-grained volcanic clasts (96-25, 103-27 and 104-28), three carry phyllite (fine-grained, mica-rich metamorphic rocks) (97-26, 101-26 and 103-27) and three granite/granophyre (95-25, 96-25 and 101-26).

ii. Cistercian-type pots 94-24, 97-26, 102-27 and 108-28 differ from the other five, as they do not carry significant amounts of 'exotic' rocks. Sherds 97-26 and 108-28 are similar to each other, but sherd 102-27 has larger clasts.

iii. Sherd 94-24 is unusual in having ?glaze ?clasts within a very clean paste and has so very few natural, non-plastics that a secure provenance is unlikely to be determined petrographically.

Comparison with other sites

Group (i) samples are unlike Wednesbury, Burslem and Ticknall but have similarities with the Nuneaton Cistercian-type wares (other than the Bordesley Abbey pots carrying chert clasts); however, the fine-grained nature of the non-plastics makes any interpretation speculative.

Group (ii) samples are all unlike the Cistercian-type fabrics found at Nuneaton, Burslem and the majority at Wednesbury, but are similar to Wednesbury 1-1, 5-1 and the red paste in 9-2.

Table 8 Cistercian-type wares: summary of select petrographic characteristics

Sample ref	**quartz <0.1mm**		**quartz 0.1–0.25**		**quartz 0.25–0.5**		**>quartz 0.5**		**opaques**		**rock type**		**voids**			**notes**
	rounding	**abundance**	**rounding**	**abundance**	**rounding**	**abundance**	**rounding**	**abundance**	**abundance**	**size range**	**rock type**	**size range**	**length**	**width**	**abundance**	
1-1 W	rounded	abundant	sub-rounded	rare	sub-rounded	rare		none	rare	<0.5	?		0.5	<0.1	rare	
4-1 W	rounded	abundant	rounded	rare	rounded	sparse		none	none		?		1.0	0.5	rare	
5-1 W	rounded	abundant	rounded	rare		none		none	none		?		0.7	0.1	sparse	
9-2 W	rounded	abundant	rounded	abundant	rounded	sparse		none	none		cloudy	0.3–0.5	1.0–2.0	0.3–0.5	frequent	
10-2 W	rounded	moderate	rounded	abundant		none		none	rare	0.2	?		1.0–1.5	0.5	rare	
21-6 B	rounded	rare	rounded	rare	rounded	very rare		none	rare	0.2–0.4	brown cloudy	0.3	0.5–2.0	0.2	sparse	
22-6 B	rounded	abundant	sub-rounded	rare	sub-rounded	rare		none	sparse	0.2–1.0	brown white cloudy	0.2–0.5	0.5–1.0	0.5–10	sparse	Polylithic rock clasts.
23.6 B	rounded	moderate		none		none		none	rare	0.7	cloudy	0.2	0.3–1.5	0.2	rare	
31.8 B	rounded	abundant		none		none		none	rare	0.2	brown cloudy	0.1–0.2	1.0–2.0	0.2	sparse	Description of main clay
32.8 B	rounded	abundant	rounded	sparse		none		none	sparse	1.0	brown cloudy	0.1–0.2	1.0	1.0	sparse	?Polylithic rock clasts.
42-10 N	rounded	moderate	rounded	sparse	sub-rounded	moderate		none	very rare	0.2	cloudy	0.2 – 0.4	3.5	0.5	rare	Single large void.
44-10 N	rounded	abundant	sub-rounded	sparse	sub-rounded	rare		none	very rare	0.2	cloudy	0.3–0.5	0.5	0.5	sparse	
75-19 L	rounded	sparse	rounded	rare	Sub-rounded	none		none	none		cloudy	0.2	1.0	0.2	sparse	Rare rock clasts
77-19 L	rounded	rare	rounded	sparse		none		none	none		cloudy	0.2–0.5	1.0	0.5	sparse	Rare, polylithic rock clast
79-19 L	rounded	abundant	rounded	rare	sub-rounded	rare		none	rare	0.2–1.0	cloudy	0.3–0.5	5.0	1.5		Rock fragments are feldspars. Single large void
94-24 BA	rounded	sparse	rounded	rare	sub-rounded	rare		none	rare	0.5–0.7	brown cloudy	0.5–1.5	2.0	0.5	rare	Rare rock clasts look micritic Rare long voids.
95-25 BA	rounded	moderate	rounded	rare	sub rounded	moderate	sub-rounded	very rare	rare	0.2–0.5	brown cloudy	0.3–0.7	0.5	0.5	rare	
96-25 BA	rounded	abundant	rounded	rare	rounded	rare		none	rare	0.6	clear cloudy	0.3–0.7	1.0	0.3	rare	Polylithic rock clast include 'quartzite'
97-26 BA	rounded	moderate	angular	rare		none		none	none		none		1.3	0.2	rare	Rare long void/burn out?
101-26 BA	rounded	rare	rounded	rare	rounded	sparse	sub-rounded	rare	rare	0.5	brown clear	0.3–0.5	0.3	<0.1	frequent	Sparse, polylithic rock clasts.
102-27 BA	rounded	sparse	rounded	rare	sub-rounded	sparse		none	rare	0.2–0.6	cloudy	0.5	0.3	0.1	rare	Rare rock clasts. Opaques include mudclasts
103-27 BA	rounded	moderate	rounded	rare		none		none	rare	0.1	brown cloudy	0.5	0.5	0.5	sparse	Rare, polylithic rock clasts. Micrite?
104-28 BA	rounded	sparse	rounded	rare	sub-rounded	sparse		none	rare	0.5–0.7	brown	0.2–2.0	1.7	0.4	sparse	Sparse, polylithic rock clasts
108-28	rounded	rare	rounded	rare		none		none	none		brown	0.3	1.0	0.3	rare	Very rare rock.

BA																
Tuck4270	rounded	abundant	rounded	rare		none		none	none		none		2.0	0.5	rare	
Tuck4278	rounded	abundant	rounded	rare		none		none	rare	0.2–0.5	brown	0.4	2.0	0.3	sparse	

7.3.2 Synoptic results for the Midlands purple wares

Production centres

Wednesbury

There is very little of distinction petrographically in these pots. They have very similar fabrics comprising monocrystalline quartz some with ?syntaxial quartz overgrowths (11-3, 16-4 and 17-4) and with minor to trace amounts of potassium feldspar. Rock fragments are less abundant than single quartz grains and comprise meta-sandstone/quartzite, sandstone, sedimentary chert plus stretched quartz (11-3 and 17-4). 'Exotic' rocks are very rare but include phyllite (11-3) and fine-grained feldspathic rocks (11-3, 16-4, 20-5).

Wednesbury sits on Coal Measure sediments including fireclays and the local drift comprises Boulder Clay and sands and gravels. Due to the absence of anything diagnostic or unusual it is almost impossible to provenance the raw materials used in the manufacture of these pots. Any clean sand combined with clean clay or a single silty clay from the above geological formations would be suitable.

Burslem

The five sherds have very similar fabrics comprising monocrystalline quartz with syntaxial quartz overgrowths (absent in 26-7 or 38-9) and minor to trace amounts of potassium feldspar. Rock fragments are less abundant than monocrystalline quartz and comprise meta-sandstone/quartzite, sandstone, sedimentary chert plus stretched quartz (37-9 and 39-9). 'Exotic' rocks are rare, but include granophyre/granite (26-7 and 28-7) fine-grained tuffs (28-7, 37-9 and 39-9), felsite (28-7 and 38-9) and phyllite (26-7 and 27-7).

Burslem sits on the Coal Measures with its abundant clays/mudstones but in the absence of anything diagnostic or unusual it is almost impossible to provenance the raw materials used in the manufacture of these pots more precisely. Any combined clean sand and clay or, single silty clay would be suitable.

Comparison with other sites

Sampled Midlands purple wares from Burslem have a slightly greater range of 'exotic' rocks than those from Wednesbury.

Ticknall

Both samples carry monocrystalline quartz accompanied by trace amounts of potassium feldspar. Rock clasts comprise meta-sandstone/quartzite, stretched quartz and chert. 'Exotic' rocks are absent to extremely rare.

Macroscopically Ticknall Cistercian-type and Midlands purple wares can be distinguished from each other on grain size. Although Vince (2007) suggests that at Ticknall two different clay types were used in Cistercian-type and Midlands purple ware manufacture, the extremely limited data (four samples, 2 of each type) in this study do not confirm this but suggest very similar raw materials were used.

Ticknall potting clays are believed to derive from the local Coal Measures (Boyle 2002–3) and the petrography of the Ticknall Midlands purple pots is consistent with that but due to the absence of anything diagnostic or unusual any other clean, silty clay (or combined clean clay and clean sand) would be suitable.

Comparison with other sites

Unlike sampled Midlands purple wares from Wednesbury and Burslem there are no 'exotic' rocks from the two Ticknall Midlands purple samples.

Nuneaton

The samples carry monocrystalline quartz with rare ? syntaxial quartz overgrowths accompanied by trace amounts of potassium feldspar. Rock clasts are equal or more abundant (53-12) in number than single grains and include meta-sandstone/quartzite and many different sorts of sandstone, and most samples have chert and quartz mosaics. 'Exotic' clasts include fine-grained, feldspathic igneous rocks (felsite) (51-12, 53-12 and 54-13), granite/granophyre (48-11, 51-13, 53-12 and 54-12) and phyllite (all except for 51-12).

Williams (1984) petrographically described 'fabric D' ('Midland purple') from Chilvers Coton as having 'much quartz 0.05 – 0.4mm in diameter with mica, rare potassium feldspar, quartzite, sandstone and sandy shale'. This description is very close to the present ones and, if 'sandy shale' is the same as 'phyllite', both would be similar in appearance if not in genesis.

Nuneaton sits at or close to the junction between the Middle and Upper Coal Measures and Triassic rocks, the Mercia Mudstones. In addition a series of very old (Pre-Cambrian and Cambrian) igneous rocks, quartzites and fine-grained meta-sediments lies within a kilometre or so as do Recent alluvial deposits.

Comparison with other sites

There are noticeable differences between Nuneaton and Wednesbury, Burslem and Ticknall non-plastics, namely the relative increase in rock clasts notably phyllite and feldspathic/granitic rocks in the Nuneaton samples. These may suggest a contribution to the raw materials at Nuneaton from rocks older than the Coal Measures.

Consumer sites

Austin Friars, Leicester

At least two populations may be present:

Population (i) comprises sherds 80-20, 90-22, 92-22 and 93-23. These are characterised by syntaxial quartz overgrowths on single quartz grains, minor to trace amounts of potassium feldspar, a range of igneous 'exotics' and polycrystalline rock clasts similar to, or equal in amounts to, monocrystalline quartz grains. They comprise meta-sandstone/quartzite, sandstones and sedimentary chert and stretched quartz (90-22, 92-22). Granite/granophyre is present in 80-20 and 93-23 and fine-grained metamorphic and volcanic rocks in 80-20, 90-22, 92-22 and 93-23.

These Midlands purple pots from Leicester are unlike the limited number of pots from Ticknall and are less like Midlands purple pots from Wednesbury and Burslem than their Cistercian-type counterparts, but they do share characteristics with Midlands purple fabrics from Nuneaton.

Population (ii) comprises 81-20, 82-20, 87-21 and 88-21, these have fewer rock clasts, than single quartz grains and are dominated by large monocrystalline quartz. The rock clasts are meta-sandstone/quartzite, sandstones but not chert and include stretched quartz (88-21) and granite/granophyre (82-20 and 87-21). They are unlike the Nuneaton Midlands purple wares but share similarities with Midlands purple wares from Burslem; they are less like pots from Wednesbury or Ticknall.

Table 9 Midlands purple wares: summary of select petrographic characteristics

Sample ref	quartz <0.1mm		quartz 0.1–0.25		quartz 0.25–0.5		>quartz 0.5		opaques		rock		voids			notes
	rounding	**abundance**	**rounding**	**abundance**	**rounding**	**abundance**	**rounding**	**abundance**	**abundance**	**size range**	**rock type**	**size range**	**length**	**width**	**abundance**	
11-3 W	round	sparse	round	sparse	Sub-rounded	moderate	sub-rounded	rare	sparse	0.5–1.0	clear cloudy	0.3–0.9	2.0	0.5	moderate	Sparse rock. clear and cloudy brown
14-3 W	round	sparse	round	rare	round	sparse		none	moderate	0.2–1.0	brown cloudy	0.4	2.0–2.5	0.7	sparse	Sparse rock clear and cloudy brown.
16-4 W	round	sparse	round	rare	sub-rounded	sparse		none	rare	0.2–1.5	clear	0.3–0.5	2.0	0/3	rare	Mudclasts to 1.5mm
17-4 W	round	moderate	round	rare	sub-rounded	sparse		none	sparse	0.1–0.5	brown cloudy	0.3–0.7	0.5	0.5	sparse	
20-5 W	round	moderate	round	rare		none		none	sparse	0.1–0.5	clear	0.2–0.8	0.5–1.5	0.5	moderate	Trace polylithic rock clasts
26-7 B	round	rare	round	moderate	round	moderate	sub-angular	rare	sparse	0.1–1.0	sparse	0.2–2.5			none	Opaques are reddened clay/mud. Single. Large, angular rock clast.
28-7 B	round	abundant	round	sparse	round	moderate	round	rare	sparse	0.2–1.0	white cloudy	0.2–0.5			none	Most opaques reddened mud/clay
37-9 B	round	sparse	round	rare	round	moderate		none	sparse	1.0–1.5	white cloudy	0.2–0.5	0.5–2.5	0.4	sparse	Opaques black. Long, linear voids
38-9 B	round	moderate	round	sparse	round	moderate		none	sparse	0.1–0.3 0.2–1.0	white cloudy	0.2–0.5	1.0	0.3	sparse	Small, round, black opaques. Large round reddened clay/mud
39-9 B	round	moderate	round	sparse	round	sparse		none	sparse	0.1–0.3 2.0	white cloudy	0.2–0.5	1.2	0.2	rare	Rounded opaques are reddened mud/clay
46-11 N	round	abundant	sub-rounded	sparse	sub-rounded	moderate		none	rare	0.5–1.0	pale brown	0.5–2.5	0.5–1.5	0.2–1.0	sparse	Many pale brown, angular ?rock clasts
48-11 N	round	abundant	round	abundant	round	sparse		none	rare	0.1–0.7	pale brown white cloudy	0.2 0.5	0.5	0.1	moderate	Polylithic rock clasts
51-12 N	round	sparse	sub-rounded	sparse	sub-rounded	moderate		none	sparse	0.1–0.5 1.0	pale yellow	0.2–2.5	0.5	0.1	sparse	Small reddened mud/clay. Angular, fine-grained rock clasts. Larger rounded opaques.
53-12 N	round	sparse	round	rare	sub-rounded	moderate		none	sparse	0.2–1.5 0.5	white cloudy	0.2–0.5	3.5	0.5	rare	Opaques are reddened mud/clay. Single, round opaque. Large single void
54-13 N	round	sparse	round	rare	sub-rounded	moderate	sub-rounded	rare	sparse	0.1–0.5	white cloudy	0.2–0.5	1.0	0.1	moderate	
55-14 N	round	rare		none	sub-rounded	moderate		none	sparse	0.2–2.0	white cloudy	0.2–0.5	0.5	0.1	sparse	Opaques are reddened clay/mud

											micrite	1.0				
80-20 L	round	abundant	round	rare	sub-rounded	sparse	sub-rounded	rare	sparse	0.1–0.4	white cloudy yellow	0.2–0.7 0.5–0.7	1.5	1.5	very rare	Polylithic rock clasts. Single irregular void.
81-20 L		none		none	sub-rounded	sparse	sub-rounded	rare	sparse	0.1–1.0	white cloudy	0.5	0.3–1.5	1.5	sparse	Opaques are ?oxidised pyrite.
82-20 L	round	sparse		none	sub-rounded	moderate	sub-angular	rare	Rare	0.2–1.0	white clear	0.3–2.5	6.0	2.0	sparse	Opaques are reddened mud/clay. Radiating thin voids are rare but large.
87-21 L	round	sparse		none	sub-rounded	sparse	sub-angular	moderate	sparse	0.2–1.0	white cloudy	0.5–0.7			none	Opaques associated with gas bubbles.
88.21 L	round	rare		none	sub-rounded	sparse	sub-rounded	sparse	sparse	0.1–0.5	mud clast	1.00	0.5	0.1	rare	Opaques are ?oxidised pyrite.
90-22 L	round	rare	round	rare	round	sparse	sub-rounded	rare	moderate	0.2–1.0	cloudy	0.3			none	Opaques are reddened mud/clay
92-22 L	round	rare		none	round	sparse	round	rare	sparse	0.2–0.7	cloudy	0.5–2.0	0.5–4.0	0.1–0.5	abundant	Opaques are reddened mud/clay
93-23 L		none	sub-rounded	abundant	sub-rounded	abundant		none	rare	0.5–1.0	white cloudy	0.2–0.6	1.0	0.1	moderate	
Tuck 4266	round	sparse		none	sub-rounded	sparse		none	rare	1.0–1.5	clear cloudy	0.5	1.0	1.0	?sparse	Poorly made uneven slide.
Tuck 4283	round	moderate		none	sub-rounded	rare	sub-rounded	moderate	rare	0.2–0.5	none		none			Opaques are ?oxidised pyrite.

7.3.3 Conclusions

Sample size

For many localities the number of Cistercian-type samples is very small. For Ticknall and Nuneaton (n=2) and Austin Friars, Leicester (n=3), and this limits the usefulness of their data and puts severe constraints on any comparisons between them.

Origin of the ceramic raw materials

Wednesbury, Burslem, Nuneaton and Ticknall, all known or proposed manufacturing centres for both Cistercian-type and Midlands purple, overlie, or are very close to, Upper Carboniferous sediments including many suitable potting clays. The petrography of the Midlands wares from these localities is quite consistent with that.

Nuneaton is the only locality close to outcrops of older sediments/metasediments and igneous rocks and their presence may explain the enhanced number and variety of 'exotic' clasts in the pots from Nuneaton. If this is so then it might suggest that Recent clays/sands were being used rather than Upper Carboniferous ones, unless these Upper Palaeozoic sediments incorporated, locally sourced, Lower Palaeozoic/Pre-Cambrian rocks.

Some general observations about the ceramics

Discrimination between Cistercian-type pots manufactured or found from different localities is inherently more difficult than discriminating between Midlands purple ceramics from different places. This is because:

a) generally, Cistercian-type wares are more restricted in the composition and grain size of their non-plastics (they are quartz dominated and the non-plastic are fine-grained), and;

b) the Cistercian-type wares lack, or have far fewer, 'exotic' rock fragments.

Cistercian-type wares clays are generally better mixed (or are manufactured from very clean clays) with only one Cistercian-type paste (103-27) having silty layers mixed within a finer main paste, unlike the Midlands purple wares where fine and silty layers were present in exactly half of the 26 pots.

Midlands purple and Cistercian-type wares differ from each other in grain size, generally the non-plastics being larger in Midlands purple wares, and larger rock clasts are easier to identify than small ones. This is a partial explanation for the greater presence of 'exotic' clasts in Midlands purple wares. However, there is probably an inherent difference in their relative amounts.

The Midlands purple wares are less uniformly fired on a microscopical scale and carry a greater anthropogenic 'non-plastic' component in the form of ?over-fired clay/vitrified clay and slag-like elements. These are often dark-coloured/opaque with gas bubbles.

Although also noted rarely for the Cistercian-type fabrics, much potassium feldspar in Midlands purple pots has been lost/removed during the slide manufacture. This phenomenon is unexplained and un-noticed before and it is not known if it has any archaeological significance and so has something to tell about the pot's composition, or manufacture, or firing, or all of these, or if it has occurred during slide manufacture and is a nuisance.

It could be concluded that, in general, if the same clay were used for both Cistercian-type and Midlands purple wares and in that clay, the bulk of the exotics occurred as larger grains, >0.3mm in diameter, then some Cistercian-type wares could be 'cleaned' versions of Midlands purple clays.

Tentative conclusions from the petrographical results for Cistercian-type and Midlands purple sherds

As shown in Table 10 the limited number of Cistercian-type pots from Austin Friars Leicester (3) may be from different sources but all the pots have fabrics that are quite dissimilar to Nuneaton Cistercian-type wares. By contrast Cistercian-type wares from Bordesley Abbey clearly show at least two separate sources; most have fabrics that are like Nuneaton-made pots and slightly fewer that are not, but show slight similarities to the less common fabrics from Wednesbury.

Midlands purple wares found at Austin Friars Leicester have at least two origins, half of the samples having similar fabrics to samples from Nuneaton, and half most closely resembling samples from Burslem, a possible other source.

ware type	consumer site	production centres				
		Wednesbury	**Burslem**	**Ticknall**	**Nuneaton**	**other source**
Cistercian-type	**Bordesley Abbey**	Few slightly similar	All are dissimilar	All are dissimilar	Most are similar	Possible. Nuneaton-like
Cistercian-type	**Austin Friars, Leicester**	Similar	Similar	Similar	Dissimilar	-
Midlands purple	**Bordesley Abbey**	-	-	-	-	-
Midlands purple	**Austin Friars, Leicester**	Slightly similar	Half similar	Dissimilar	Half similar	Possible

Table 10 Broad correlation of consumer sites with production centres based on petrographical data

7.4 Glaze study (*by* R A Ixer)

For the detailed glaze study reports see Appendix 4.

A preliminary investigation was undertaken to determine if reflected light studies could be of use in British medieval pottery studies. A total of six glazed Cistercian-type ware sherds were selected by D Hurst as suitable material.

7.4.1 Introduction to the use of reflected light petrography in an archaeological context

Transmitted light petrography of pottery sherds, using standard thin sections, ground down to 30μm thickness, is the most common, non-chemical, method of ceramic investigation, and is extensively used for provenance studies. Standard thin sections have a thin glass cover slip to protect their surface.

However, transmitted light petrography is only applicable for translucent materials and has a number of limitations. The technique can tell little about optically isotropic materials (these are mainly glasses) or opaque minerals (these are mainly metal oxides and sulphides) as both appear 'black' in crossed polarised light; in addition, as the name suggests, opaques are also black in plane-polarised light. In addition, fine-grained minerals, most notably phyllosilicates and clays, are difficult to resolve and identify through the glass cover slip. Hence, other than their colour and crystal habit/form little can be discerned about isotropic, or opaque or very fine-grained phases using transmitted light petrography. All three classes of material and especially clays are widespread and important in ceramics.

Reflected light petrography is in many ways a complementary method to transmitted light and is intended for the investigation of opaque phases. It has its main use in the investigation of metal ores for the mining industry, and essentially the same technique is used in metallography. Reflected light uses solid, polished blocks or, more often, polished thin sections. These are prepared in the same way as standard thin sections but instead of a cover slip, the top surface of the sample is polished until it has a mirror-like finish (indeed the finish needs to be better than mirror-like and for the best results the final polish uses 0.25µm diamond paste). Ideally the sections have the standard 30µm thickness but often are slightly thicker to avoid the accidental, but selective, removal of softer phases. The advantage of a polished thin section over a standard thin section is that it can be used to investigate all the mineralogy/phases of a sample, successively using transmitted light and reflected light petrography. In addition by their very nature they have to have a better finish than standard thin sections so that finer materials (clays) can be described. Finally, sections are also already prepared for subsequent 'black box', analysis by SEM or microprobe and only need to be coated with a conducting material before further analyses can be made. Details on how polished thin sections are prepared, what material should be chosen and examples of many opaque minerals and their associations are given in Ixer (1990).

Although total petrography, especially when combined with whole rock geochemistry, has proved to be a powerful tool in the provenancing of archaeological lithics (Ixer 1994, 1997; and Ixer *et al* 2004) only rarely has it been applied to provenancing ceramics (Ixer and Vince 2009). This is because for most ceramics, especially those that are essentially quartz sand tempered, total petrography is little better than transmitted light petrography and there are very few ore microscopists willing to undertake the work.

However, reflected light petrography in ceramics has been shown to be important in distinguishing and provenancing opaque-bearing temper – essentially distinguishing between different classes of igneous rocks and slags (Cumberpatch *et al* 2005), distinguishing glacial from deep water anoxic clays (the latter have framboidal pyrite and fine-grained carbonaceous matter; Ixer in prep.), the correct identification of rounded 'iron oxides' (limonite, fine-grained haematite pigment and organic matter), and in the examination of glazes (Barker 1986).

Glazes are by their very nature glassy and hence optically isotropic, therefore they are difficult to investigate using transmitted light petrography. Recrystallisation products within the glaze and the presence of included silicate phases can be distinguished, but little else; mostly they are investigated using a hand lens followed by chemical analysis including INAA or SEM-EDX or yet more sophisticated micro-analytical techniques.

Despite this, some reflected light work has been done on English mediaeval glazes. Preliminary work on 28 polished thin sections of medieval and post-medieval pottery from the English Midlands including both Cistercian and Midlands purple wares suggested that the iron oxides haematite and magnetite were the dominant opaques within the glazes, that they crystallised *in situ* and could be distinguished from the same phases, but initially occurring as detrital, oxide minerals, within the main body of the pot. This showed that these oxides in the glaze were neomorphic rather than residual. Other than trace amounts of copper metal and copper oxide in a green glaze on a buff-white sandy ware from Sandwell Priory and widespread but trace amounts of ?TiO_2 phases, no other metal phases were recognised (Ixer 1992).

Similarly, reflected light microscopy and qualitative chemical analysis (?SEM- EDX) of the glaze on a single polished block of Cistercian ware from Hulton Abbey showed the presence of small iron oxide crystals, and that they were concentrated at the clay-glaze boundary and that no other colouring agent was present (Barker 1986).

Glaze studies on non-British medieval and post-medieval ceramics are abundant but are mainly chemical in nature.

7.4.2 Results

The present study concentrates on six sections of Cistercian-type wares 1-1, 5-1, 21-6, 32-8, 42-10 and 44-10, and essentially refines the earlier studies of Ixer and Barker.

Cistercian-type ware

Six polished thin sections 1-1, 5-1, 21-6, 32-8, 42-10 and 44-10 were investigated in both reflected and transmitted light.

Reflected light studies of the main body of the pot

The clays vary in colour from pale yellow brown (21-6) to very dark brown (32-8, 42-10, 44-10). In all cases other than 21-6 the main clay carries abundant haematite pigment (acicular haematite <<1 to 2µm in length) in addition to newly formed haematite crystals up to 20µm and pale coloured TiO_2 minerals most of which are 2–20µm in diameter. The lack of fine-grained disseminated haematite pigment with its characteristic red internal reflections appears to be the cause of the pale colour of the main clay in 21-6. However, for the other pots there appears to be no strong correlation between firing colour of main clay and presence of iron oxides or size and density of the fine-grained haematite pigment. Short phyllosilicate laths 60–120 but up to 200µm in length have fine-grained haematite pigment along their cleavage planes.

There is nothing unusual about the main clays used to manufacture any of these six ceramics. The lack of framboidal pyrite or its fired equivalent suggests that these clays were not deep-water clays from the Mesozoic succession of England.

Detrital, ex-iron titanium oxide minerals now comprise very fine-grained mixtures of haematite and ? pseudobrookite and are 20–50 but up to 120µm in diameter. The petrographical variation in the detrital opaque fraction between the ceramics is slight and the opaques are similar to those found in many fine-grained sediments. However, the presence of fine-grained haematite-pseudobrookite intergrowths rather than haematite-TiO_2 mineral intergrowths (as is seen in unfired clays) is of note and, if the identification is correct, suggests heating to at least 800-850°C (Saito *et al* 2004). This again confirms that generally opaques are less useful than silicates in distinguishing between ceramics from different places.

Irregular to rounded areas of fine-grained haematite pigment, 40–200µm in diameter, are probably fired mud clasts where the original limonite (a mixture of iron oxides and hydroxides) has been altered to fine-grained haematite; others comprise fine-grained quartz cemented by very fine-grained haematite (?heated limonite). They are neither organic nor anthropogenic but probably natural.

The lack of fine-grained haematite pigment in 21-6 may suggest that it has been fired to a higher temperature than the pigment-bearing pots and that the iron has been incorporated into iron-bearing silicates rather than remaining as discrete oxides.

Reflected light studies of the glaze

The opaques are systematically distributed. Fine-grained <1–5µm diameter, equant, magnetite (Fe_3O_4) lies close to the clay junction, whereas the more oxidised iron phase haematite (Fe_2O_3) is present closer to the surface of the glaze. This suggests that the iron, supplied by the clay, passes into the glaze and is progressively oxidised by the atmosphere. Boyle (2002–3, 114) notes that 'recent studies suggest that the iron content of the clays was sufficient to create the brown black colour of the glaze', and the detailed petrography of the glazes is in agreement this.

Haematite (α-Fe_2O_3) is the main opaque phase in all the pot glazes other than 21-6 where there is very little opaque oxide. It varies in amount from trace to minor and occurs as thin, acicular laths and hexagonal basal plates <1 –60µm in length, the size of the crystals increasing away from the clay-glaze contact as the number of crystals decreases. In some pots (5-1, 42-10 and 44-10) haematite laths (probably basal hexagonal crystals seen end-on) lie along the top surface of the glaze.

Haematite is accompanied by minor amounts of a cubic phase with the optical properties of magnetite (5-1, 21-6 and 44-10) and by trace amounts of a semi-opaque phase with brown internal reflections that may be a TiO_2 mineral. This phase is more noticeable in 21-6.

No other opaque phases were recognised or suspected. Adventitious matter in the glaze mainly comprises monocrystalline quartz grains and very rare opaques. There is no reaction between the quartz and glaze, but the opaques have recrystallised into fine-grained magnetite or haematite aggregates.

Transmitted light studies of the glaze

It is not possible to distinguish magnetite from haematite in transmitted light other than very crudely by using their crystal habits; magnetite forms cubic, equant or skeletal crystals, whereas haematite forms laths and basal hexagonal crystals (Ixer 1991). This method is unreliable and, in addition, haematite pseudomorphs after magnetite (a very common phenomenon) will be indistinguishable from the parent magnetite. Despite this and by extrapolating from glaze studies in the polished thin sections it is possible to make a few generalised observations.

All the pots are glazed but there is no standard thickness as they vary from thin <0.1mm (22-6) to thick 1.5mm (101-26). However most glazes are between 0.2–0.5mm thick and only 31-8 and 101-26 have glazes that are thicker than 0.5mm. Locally the thickness of a single glaze corresponds with petrographical differences within it, as thicker glazes are usually mineralogically more complex than thinner ones. The vast majority comprise an isotropic glassy glaze that shows no sign of recrystallisation (94-24 may show, very local recrystallisation) and only carry minor amounts of opaques and/or radiating anisotropic material within. Although these acicular, anisotropic crystals are probably a silicate (?mullite or potassium feldspar) they may be very fine-grained haematite; they are especially well-developed in 23-6, 94-24 and 104-28.

A common glaze is weakly zoned and comprises main clay passing into a thin zone of pale brown, very thin, acicular crystals with first order interference colours themselves passing out into an opaque-free clear glaze (good examples include 9-2, 10-2, 75-19, 77-19, 79-19, 97-26, 101-26 and108-28). The texture at the clay-glaze junction suggests a glaze-clay interaction.

Other glazes show more colour zoning and are opaque-bearing, the shapes of the opaques suggesting that haematite is more common than magnetite, and that the relationship between the two oxides, as seen in polished thin section, is also true. Some glazes show no reaction rim at the clay-glaze junction and these include 102.27 and the two Ticknall sherds (56-15 (V4270) and 68-17 (V4278)).

Midlands purple ware

Transmitted light studies of the glaze

No polished thin sections of Midlands purple ware were produced.

There is less uniformity than is shown by the Cistercian-type wares and it is difficult to distinguish between true glazes, slag-like possible glazes (?54-13) and possible vitrified fusion crusts (?28-7, 51-12, 53-12 and 90-22).

Midland purple sherds vary from having no glaze – most of the Austin Friars Leicester sherds are unglazed (only 93-23 is clearly glazed) – to having a very thick glaze; 16-4, 39-9 and 73-18 (V4283) have glazes 1.0mm, 0.8mm and 6 mm thick respectively. Most glazed pots, however, have a very thin, < 0.1–0.2mm glaze. The glazes are similar in range to those described for the Cistercian-type wares, namely some having no oxides but having ?mullite/potassium feldspar (73-18; Ticknall V4283), others carrying opaque phases that have habits suggesting the presence of haematite (11-3 and 20-5) or haematite and magnetite 16-4 (some as entrained opaques) plus a lath-shaped anisotropic phase that may be mullite (39-9).

7.4.3 Conclusions

Glaze study was not able to add any specific information about the characterisation or provenance of this material.

7.5 Collated summary of results of analysis

In total 90 ICPS new samples were run, making 109 in total when combined with Alan Vince's samples, and 51 thin sections petrographically analysed. The fabrics of all sherds were also classified by eye (macroscopically, and microscopically at x20 magnification), and as a result 30 separate fabrics were identified and recorded. For the more detailed technical data and reports see the Appendices 2–4.

The basic problem which this research was designed to address was that most of the Midlands purple and Cistercian-type ware products in the west Midlands could not be distinguished from one another. The intention of the research was to try and establish markers for the identification of these wares, preferably at a macro-/microscopical level (max x20 magnification) but based on a firm foundation of differentiation established by the scientific data on the clay chemistry (ICPS) and possibly on specific mineralogy and general high magnification description (petrographic and glaze study of thin sections).

The ICPS results have proven indicative of all the samples being associated with their respective production centres, and these data are, therefore, valid for characterising these centres for future reference. This outcome is of considerable importance for this research as it has enabled the results of other investigative work (especially the identification of fabrics by eye) to then be applied towards the general identification of this material, and henceforward the differentiation of one production from another, though centres identified by the ICPS as producing a particular pottery type were not always identifiable to a known location.

sample refs	ICPS analysis	sample group	place	site	pot type	waster?	visual fabric	published fabric ref	ICPS group	TS?	TS group
1	REA01	1	Wednesbury	Lower High Street	Cist	No	A		PCA C-Wednes	Yes	
2	REA02	1	Wednesbury	Lower High Street	Cist	No	A		PCA C-Wednes	No	
3	REA03	1	Wednesbury	Lower High Street	Cist	No	A		PCA C-Wednes	No	
4	REA04	1	Wednesbury	Lower High Street	Cist	No	?A		PCA C-Wednes	Yes	
5	REA05	1	Wednesbury	Lower High Street	Cist	No	A		PCA C-Wednes	Yes	
6	REA07	2	Wednesbury	Town centre	Cist	No	AE		PCA B-unknown	No	
7	REA08	2	Wednesbury	Town centre	Cist	No	AE		PCA B-unknown	No	
8	REA09	2	Wednesbury	Town centre	Cist	No	A		PCA C-Wednes	No	
9	REA10	2	Wednesbury	Town centre	Cist	Yes	?A		PCA C-Wednes	Yes	
10	REA11	2	Wednesbury	Town centre	Cist	No	A		PCA C-Wednes	Yes	
11	REA12	3	Wednesbury	Lower High Street service trenches	MP	Yes	B			Yes	
12	REA13	3	Wednesbury	Lower High Street service trenches	MP	No	B			No	
13	REA14	3	Wednesbury	Lower High Street service trenches	MP	No	B			No	
14	REA15	3	Wednesbury	Lower High Street service trenches	MP	No	C			Yes	
15	REA16	3	Wednesbury	Lower High Street service trenches	MP	Yes	B			No	
16	REA17	4	Wednesbury	Market Place	MP	No	D			Yes	
17	REA18	4	Wednesbury	Market Place	MP	No	B			Yes	
18	REA19	4	Wednesbury	Market Place	MP	No	?D			No	
19	REA20	5	Wednesbury	Meeting Street	MP	No	?C			No	
20	REA21	5	Wednesbury	Meeting Street	MP	No	D			Yes	
21	REA22	6	Burslem	Market Place	Cist	No	E			Yes	
22	REA23	6	Burslem	Market Place	Cist	No	F			Yes	
23	REA24	6	Burslem	Market Place	Cist	No	G			Yes	
24	REA25	6	Burslem	Market Place	Cist	No	G			No	
25	REA26	6	Burslem	Market Place	Cist	No	H			No	

26	REA28	7	Burslem	Market Place	MP	No	I			Yes	
27	REA29	7	Burslem	Market Place	MP	No	I			No	
28	REA30	7	Burslem	Market Place	MP	No	I			Yes	
29	REA31	7	Burslem	Market Place	MP	No	I			No	
30	REA32	7	Burslem	Market Place	MP	No	I			No	
31	REA33	8	Burslem	School of Art	Cist	No	H			No	
32	REA34	8	Burslem	School of Art	Cist	No	H			Yes	
33	REA35	8	Burslem	School of Art	Cist	No	H			No	
34	REA36	8	Burslem	School of Art	Cist	No	H			No	
35	REA37	8	Burslem	School of Art	Cist	Yes	H			No	
36	REA38	9	Burslem	School of Art	MP	No	I			No	
37	REA39	9	Burslem	School of Art	MP	No	I			Yes	
38	REA40	9	Burslem	School of Art	MP	No	I			Yes	
39	REA41	9	Burslem	School of Art	MP	No	J			Yes	
40	REA42	9	Burslem	School of Art	MP	No	I			No	
41	REA43	10	Nuneaton	Chilvers Coton – kiln 34	Cist	Yes	K			No	
42	REA44	10	Nuneaton	Chilvers Coton – kiln 34	Cist	No	L			Yes	
43	REA45	10	Nuneaton	Chilvers Coton – kiln 34	Cist	Yes	L			No	
44	REA46	10	Nuneaton	Chilvers Coton – kiln 34	Cist	Yes	L			Yes	
45	REA47	10	Nuneaton	Chilvers Coton – kiln 34	Cist	No	L			No	
46	REA49	11	Nuneaton	Chilvers Coton – kiln 34	MP	Yes	M			Yes	
47	REA50	11	Nuneaton	Chilvers Coton – kiln 34	MP	No	M			No	
48	REA51	11	Nuneaton	Chilvers Coton – kiln 34	MP	Yes	M			Yes	
49	REA52	11	Nuneaton	Chilvers Coton – kiln 34	MP	Yes	M			No	
50	REA53	11	Nuneaton	Chilvers Coton – kiln 34	MP	Yes	M			No	
51	REA54	12	Nuneaton	Harefield Lane – kiln 42	MP	Yes	N			Yes	
52	REA55	12	Nuneaton	Harefield Lane – kiln 42	MP	Yes	N			No	
53	REA56	12	Nuneaton	Harefield Lane – kiln 40	MP	Yes	N			Yes	
54	REA57	13	Nuneaton	11 Bermuda Road (NB 99)	MP	Yes	?N			Yes	
55	REA58	14	Nuneaton	16–22 Bermuda Road (NCC 79)	MP	No	N			Yes	
56	V4270	15	Ticknall	Peat's Close	Cist	Yes	AC		Ticknall 1	Yes	
57	V4271	15	Ticknall	Peat's Close	Cist	No	AC		Ticknall 1	No	
58	V4272	15	Ticknall	Peat's Close	Cist	No	AC		Ticknall 1	No	
59	V4273	15	Ticknall	Peat's Close	Cist	No	AC		Ticknall 1	No	
60	V4274	15	Ticknall	Peat's Close	Cist	Yes	AC		Ticknall 1	No	
61	V4266	16	Ticknall	Peat's Close	MP	Yes	AD		Ticknall 2	Yes	
62	V4267	16	Ticknall	Peat's Close	MP	No	AD		Ticknall 2	No	
63	V4268	16	Ticknall	Peat's Close	MP	No	AD		Ticknall 2	No	
64	V4269	16	Ticknall	Peat's Close	MP	No	AD		Ticknall 2	No	
65	V4275	17	Ticknall	Church Lane	Cist	No	AC		Ticknall 1	No	
66	V4276	17	Ticknall	Church Lane	Cist	No	AC		Ticknall 2	No	
67	V4277	17	Ticknall	Church Lane	Cist	No	AC		Ticknall 2	No	
68	V4278	17	Ticknall	Church Lane	Cist	Yes	AC		Ticknall 2	Yes	
69	V4279	17	Ticknall	Church Lane	Cist	No	AC		Ticknall 2	No	
70	V4280	18	Ticknall	Church Lane	MP	No	AD		Ticknall 2	No	
71	V4281	18	Ticknall	Church Lane	MP	No	AD		Ticknall 2	No	
72	V4282	18	Ticknall	Church Lane	MP	No	AD		Ticknall 2	No	
73	V4283	18	Ticknall	Church Lane	MP	No	AD		Ticknall 2	Yes	
74	V4284	18	Ticknall	Church Lane	MP	No	AD		Ticknall 2	No	
75	REA59	19	Leicester	Austin Friars	Cist	No	P	CW	PCA C-Wednes	Yes	?Wednesbury
76	REA60	19	Leicester	Austin Friars	Cist	No	Q	CW	Ticknall 1	No	
77	REA61	19	Leicester	Austin Friars	Cist	No	R	CW	PCA C-Wednes	Yes	?Ticknall
78	REA62	19	Leicester	Austin Friars	Cist	No	R	CW	Ticknall 1	No	
79	REA63	19	Leicester	Austin Friars	Cist	No	Q	CW	Ticknall 1	Yes	
80	REA64	20	Leicester	Austin Friars	MP	No	S	P(XIIII)	Similar to Nuneaton	Yes	?Nuneaton
81	REA65	20	Leicester	Austin Friars	MP	No	T	P(XIII)	Similar to Nuneaton	Yes	?Burslem
82	REA66	20	Leicester	Austin Friars	MP	No	U	P(XIII)	Similar to Nuneaton	Yes	?Burslem
83	REA67	20	Leicester	Austin Friars	MP	No	?U	P(XIII)	Similar to Nuneaton	No	
84	REA68	20	Leicester	Austin Friars	MP	No	?U	P(XIII)	Similar to Nuneaton	No	
85	REA69	21	Leicester	Austin Friars	MP	No	U	P(XIX)	Similar to Nuneaton	No	
86	REA71	21	Leicester	Austin Friars	MP	No	?U	P(XIX)	Similar to Nuneaton	No	
87	REA72	21	Leicester	Austin Friars	MP	No	?V	P(XIX)	Similar to Nuneaton	Yes	?Burslem
88	REA73	21	Leicester	Austin Friars	MP	No	T	P(XIX)	Similar to Nuneaton	Yes	?Burslem
89	REA74	21	Leicester	Austin Friars	MP	No	U	P(XIX)	Similar to Nuneaton	No	
90	REA75	22	Leicester	Austin Friars	MP	No	T	P(XXI)	Similar to Nuneaton	Yes	?Nuneaton
91	REA76	22	Leicester	Austin Friars	MP	No	T	P(XXI)	Similar to Nuneaton	No	
92	REA77	22	Leicester	Austin Friars	MP	No	T	P(XXI)	Similar to Nuneaton	Yes	?Nuneaton
93	REA78	23	Leicester	Austin Friars	MP	No	W	P(XXII)	Similar to Nuneaton	Yes	?Nuneaton
94	REA79	24		Bordesley Abbey	Cist	No	X	F109(I)	PCA B-unknown	Yes	?Wednesbury
95	REA80	25		Bordesley Abbey	Cist	No	Y	F109(ii)	PCA B-unknown	Yes	?Nuneaton
96	REA81	25		Bordesley Abbey	Cist	No	Y	F109(ii)	PCA B-ambiguous	Yes	?Nuneaton
97	REA82	26		Bordesley Abbey	Cist	No	Z	F109(iii)	PCA C-Wednes	Yes	?Wednesbury
98	REA83	26		Bordesley Abbey	Cist	No	?Z	F109(iii)	PCA C-Wednes	No	
99	REA84	26		Bordesley Abbey	Cist	No	Z	F109(iii)	PCA C-Wednes	No	
100	REA85	26		Bordesley Abbey	Cist	No	Z	F109(iii)	PCA C-Wednes	No	

101	REA86	26		Bordesley Abbey	Cist	No	AA	F109(iii)	Ticknall 1	Yes	?Nuneaton
102	REA87	27		Bordesley Abbey	Cist	No	Y	F109(iv)	PCA C-Wednes	Yes	?Wednesbury
103	REA88	27		Bordesley Abbey	Cist	No	Z	F109(iv)	PCA C-Wednes	Yes	?Nuneaton
104	REA89	28		Bordesley Abbey	Cist	No	AB	F109	PCA B-unknown	Yes	?Nuneaton
105	REA90	28		Bordesley Abbey	Cist	No	Y	F109	PCA C-Wednes	No	
106	REA92	28		Bordesley Abbey	Cist	No	?Y	F109	PCA B-unknown	No	
107	REA93	28		Bordesley Abbey	Cist	No	X	F109	PCA B-unknown	No	
108	REA94	28		Bordesley Abbey	Cist	No	Z	F109	PCA C-Wednes	Yes	?Wednesbury
109	REA95	28		Bordesley Abbey	Cist	No	Y	F109	PCA B-unknown	No	

Table 11 Samples with concordance of scientific and visual grouping of fabrics (see Tables 1–2 for more details of specific site origins for sample sherds)

7.5.1 Defining characteristics of production centres

The following collates the conclusions of the analytical work undertaken and applies these towards the better definition of the products of the production centres to aid any possible potential for differentiation. The collation takes the order of ICPS first, then thin section and fabric definition because the ICPS provided the best evidence for identification of groups sharing a common source (in terms of more absolute scientific data), against which both thin section analysis and fabric types (the latter as defined both macro- and microscopically) could then be compared to assess whether visual characteristics could be correlated.

Glaze and often fabric colour are here discounted as useful for the general purposes of differentiation as these are generally so variable.

Wednesbury Cistercian-type

ICPS – overall Cistercian-type ware was distinctive as a group **and** distinct from the Wednesbury Midlands purple. Wednesbury Cistercian-type ware fell into two clay chemical groups (PCA groups B and C); C is very probably Wednesbury production and B is of unknown origin, possibly another production at Wednesbury or elsewhere (see Fig 4).

TS – None of the Wednesbury fabrics (Cistercian-type and Midlands purple) as a whole exhibited any distinctive markers petrographically.

Fabric definition (macroscopic to x20) – The Wednesbury Cistercian-type ware was typically fine sandy but often with an abundant fine pale flecking (fabric A), though some was slightly coarser and lacked the flecking (AE). There was also a tendency to exhibit voids which indicated in this case poorly worked clay.

Other diagnostic criteria (macroscopic) – the main form seemed to be the double-handled cup and, where decorated, there was only a very limited repertoire of motifs (eg clay pellets stamped with a wheel design). The cup bases usually exhibit parallel striations.

Overall comparison with other production centres based on fabric

The principal Wednesbury fabric (A) seems relatively distinctive, though the other fabric-type (AE) is close visually to Ticknall fabric; the far more limited Wednesbury repertoire of form types (ie mainly cups) and of decorative motifs, should help with identification. It is also marked by having bases which exhibit parallel striations resulting from the way it was cut off the wheel-head (though similar evidence has been seen from Burslem). Fabric A corresponds with PCA group C, and fabric AE with PCA group B, the final stage of ICPS analysis (cf Fig 7) showing PCA groups B and C as distinct from Ticknall (ie both Ticknall 1 and 2).

Wednesbury Midlands purple

ICPS – Wednesbury Midlands purple is distinctive as a group and from Wednesbury Cistercian-type ware. Two of the sites (Lower High Street service trenches and Market Place) were distinguishable from each other, and possibly from the Meeting Street material.

TS – None of the Wednesbury fabrics (Cistercian-type and Midlands purple) as a whole have any distinctive markers petrographically.

Fabric definition (macroscopic to x20) – At x20 the Wednesbury Midlands purple appears to be more variable than the Cistercian-type (ie 3 MP fabrics identified); these fabrics do not correspond with the three different sites. They appear very different both in quartz content and even clay colour – though one possible shared feature is rare dark pellets which can look dark red or grey (?according to firing as per 19-5) and sometimes quite cindery (15-3).

Other diagnostic criteria (macroscopic) – None have been distinguished. However, relatively little material has been published from this production centre.

Overall comparison with other production centres based on fabric

The Wednesbury Midlands purple appears not to be visually very homogenous but not in the way suggested by the ICPS results. In the absence of any form criteria it presently seems unlikely that this material is distinctive enough to be separated easily from Midlands purple from other production centres.

Burslem Cistercian-type

ICPS – Overall the Burslem samples (both Cistercian-type and Midlands purple) were chemically distinct and the Cistercian-type ware clay chemistry was slightly different to that of the Midlands purple.

TS – There was nothing distinctive petrographically about the Burslem samples, except overall there was greater diversity of fabric types.

Fabric definition (macroscopic to x20) – Four different fabrics were defined by eye; the spread between the two sites was not consistent as four fabrics were defined for the Market Place site (no detailed fabric description was available for comparison in Boothroyd and Cortney 2004), whereas all the School of Art fabrics were much the same. Fabric H is quite distinctive as it contains larger quartz than Wednesbury or Ticknall, and it is strikingly even in grade; mainly reduced. The other fabrics do suggest a considerable range of pastes being used, though one fairly consistent inclusion type, though **rare**, is the dark red or grey/purplish (dependent on firing) iron-rich pellet, and overall the fabrics look more vitrified (and are, therefore, harder). Clearly an iron-rich clay has been used.

Other diagnostic criteria (macroscopic) – the published type-series for the Cistercian-type wares suggests that the preferred form differed from that at Wednesbury, as it was an everted rim cup which contrasts with the more bulbous and more upright and shorter rimmed cup from Wednesbury (this is a very tentative and preliminary suggestion based on the limited published evidence).

Overall comparison with other production centres based on fabric

Depending on how common fabric H is as a whole, this may be a useful indicator of Burslem Cistercian-type ware products. When other fabrics are used at present they seem not to be obviously distinct enough to be applicable to wider use (though the size of the present sample has hampered this determination, and a larger sample is required). It is just possible that the presence of the iron-rich pellets and the tendency to greater vitrification may be useful as indicators. The possibility of form differentiation from Wednesbury needs to be explored (see above), and, judging from the sampled material (though too small), the Burslem Cistercian-type seems to be cruder in form execution than for Wednesbury.

Burslem Midlands purple

ICPS – Overall the Burslem samples (both Cistercian-type and Midlands purple) were chemically distinct and the Cistercian-type ware clay chemistry was slightly different to that of the Midlands purple.

TS – There was nothing distinctive petrographically about the Burslem samples, except overall there was greater disparity of fabric types.

Fabric definition (macroscopic to x20) – The Burslem Midlands purple (fabric I) appeared to be a very consistent product which was basically very similar overall to Cistercian-type fabric H except that the quartz size was higher (0.25mm in contrast to 0.1mm), but generally just as even graded and abundant. Fabric J would appear to be a relatively slight variation where the quartz appears less in evidence as the surrounding matrix is more heavily vitrified. Overall fabric colouring at the break, where high-fired, is also very consistent as a medium purple, and it is clearly an iron-rich clay.

Other diagnostic criteria (macroscopic) – None has been specifically distinguished. A useful site form-series has been published (Boothroyd and Courtney 2004) which shows a range of forms, which includes forms separate from jar forms (eg chafing dishes).

Overall comparison with other production centres based on fabric

Since the fabric is generally relatively distinctive and consistent it would seem hopeful that Burslem Midlands purple could be distinguished by eye, and distinguished from other Midlands purple. In fabric the Burslem Midlands purple seems to be a more consistent product than the Wednesbury equivalent.

Nuneaton Cistercian-type

ICPS – Overall the Nuneaton products were chemically distinct from the other production centres, and its Cistercian-type ware was slightly different form its Midlands purple. The high proportion of wasters for both the Cistercian-type and Midlands purple provides a high level of confidence that local products were analysed.

TS – Both Cistercian-type and Midlands purple are similar to each other; there are subtle differences between the products of Nuneaton and the other production centres, in that some igneous rock can be in evidence.

Fabric definition (macroscopic to x20) – Two Cistercian-type fabrics (K and L, the latter apparently much the commoner) were identified but they were very similar to each other in that both contained abundant quartz which seemed to be in two grades (abundant <0.1mm and rare *c* 0.25mm). Fabric K also contained rare rounded fine white sandstone (rather like Wednesbury though in the latter case it was more in evidence); both have rare/sparse dark red inclusions up to 0.25mm, but they were more in evidence in the lower fired fabric K example. Occasionally the fineness in terms of the grade of quartz used for Fabric L was notable though this seemed to be an exception; of course the present number of samples is too small to be sure. Mayes' fabric E ('red-firing with no inclusions'; Mayes and Scott 1984, 197) may be comparable to fabrics K and L (this project) if it is assumed that that this refers to their macroscopic appearance, Mayes fabric E being a finer fabric than Mayes D (Midlands purple).

Other diagnostic criteria (macroscopic) – Cistercian-type ware forms are variable but this type seemed to be relatively infrequent compared to the other products of these kilns. Some of the forms have a single handle (mug form) and where double-opposing handles are used on bulbous cups (Mayes and Scott 1984, 160, fig 108) the cups are less bulbous but have a slightly taller rim than Wednesbury examples, and the rim is not as everted as for Burslem examples. Therefore, it seems likely that form criteria will also be useful for differentiating these wares.

Overall comparison with other production centres based on fabric

A combination of fabric and form may allow differentiation of Nuneaton Cistercian-type from other production centres. Nuneaton Cistercian-type ware seemed relatively distinctly different in fabric from both Wednesbury fabrics (A and AE) but more similar to the main type of Burslem Cistercian-type (fabric H), especially where Nuneaton was at its finest (in terms of the quartz being at its smallest; fabric L); generally the Nuneaton material is at least moderately sandy (some quartz being evident by eye).

There is also the possibility that some differentiation of Nuneaton material may be possible on the grounds of form, though much more study and publication of Wednesbury material is still required before this aspect can be fully assessed.

Nuneaton Midlands purple

ICPS – Overall the Nuneaton products were chemically distinct from the other production centres, and its Midlands purple was slightly different from its Cistercian-type. The high proportion of wasters for both the Cistercian-type and Midlands purple provides a high level of confidence that local products were analysed.

TS – Both Cistercian-type and Midlands purple are similar to each other; there are subtle differences between the products of Nuneaton and the other production centres, in that some igneous rock can be in evidence.

Fabric definition (macroscopic to x 20) – Two Midlands purple fabrics (M and N) were identified which mainly seemed to correlate respectively to specific sites as follows: Chilvers Coton kiln 34 (east of Bermuda Road), and Harefield Lane kilns 40 and 42 (Mayes and Scott 1984). Again these are quite similar in that both are abundantly sandy; in fabric M the quartz is all finer (0.20mm compared with 0.25–0.50mm for fabric N) and there is little sign of the moderate red/black pellets of fabric N. Visually fabric M is similar to K (the least common Chilvers Coton Cistercian-type fabric) suggesting that Cistercian-type ware was sometimes made in the less coarse of the Midlands purple ware fabrics. Mayes' Midlands purple fabric D description (though brief; Mayes and Scott 1984, 40 and Williams 1984, 197) sounds like it broadly corresponds with fabrics M and N (this project).

Other diagnostic criteria (macroscopic) – A great quantity and range of ceramics was produced by the 42 kilns excavated at Chilvers Coton in 1967–71 (Mayes and Scott 1984), though these operated from the 13th century and it is less clear how much production was happening in the 15th–16th century; however the sheer number of kilns producing Chilvers Coton Mayes fabrics D and E suggest it was extensive.

Overall comparison with other production centres based on fabric

There was a close resemblance between Nuneaton and Burslem Midlands purple as both contained abundant quartz of much the same grade, the former looking slightly more uniform than the latter. None of the Wednesbury Midlands purple had this regularity of inclusion size and this high uniformity of inclusion type and size.

Ticknall Cistercian-type

ICPS – The Ticknall Cistercian-type fell into two chemical groups. The Church Lane Cistercian-type (apart from one sherd, sample no. 65) together with all the Ticknall Midlands purple formed a chemically similar group (= Ticknall 2) which was distinguishable from other production centres. The Peat's Close Cistercian-type and one of the Church Lane Cistercian-type sherds (sample 65) formed a different chemical group (= Ticknall 1); there were similarities with PCA groups B and C, but this Ticknall group (1) remained distinguishable from these.

TS – Petrography indicates that Cistercian-type and Midlands purple have different grain sizes.

Fabric definition (macroscopic to x20) – The Cistercian-type is heavily tempered with a very fine even-sized quartz sand that is barely visible at x20; only occasional larger ? quarzite grains are visible.

Other diagnostic criteria (macroscopic) – The widespread use of applied white clay decoration is a notable feature of this ware type from both the sites sampled here, and from other Ticknall sites (Church Lane: Boyle and Rowlandson 2006–8, 13 fig 10; Spavold and Brown 2005, chapter 6). The applied decoration on Peat's Close Cistercian-type is diverse, complex and of high quality (eg lace patterns, flowers, fish and animal motifs, site 6: Spavold and Brown 2005, chapter 6). Few complete profiles have yet been published but the everted-rimmed cup does seem to be well represented (eg Peat's Close: Spavold and Brown 2005, appendix 2, no 10, site 6; Church Lane: Boyle and Rowlandson, 2006–8, 13 fig 10) which is also evident at Burslem (cf Ford 1995, 36–7 figs 21–2; Barker 1986, fig 1, nos 1–4; Boothroyd and Courtney 2004, 91–3 fig 14; referred to here as flared cups).

Overall comparison with other production centres based on fabric

In fabric this ware is generally distinguishable from Wednesbury and Nuneaton Cistercian-type wares because of its fineness of quartz, however some of the less common Burslem material was even finer (fabric G) and it was very similar to the main Burslem Cistercian-type fabric (H). Similarity in cup form also seems evident and so distinguishing Ticknall from Burslem Cistercian-type could be visually problematic. The wide range of unusual applied decoration, however, makes this ware potentially recognisable.

Ticknall Midlands purple

ICPS – All the Ticknall Midlands purple together with the Church Lane Cistercian-type (apart from one sherd, sample 65) formed a chemically similar group which was distinguishable from other production centres (=Ticknall 2).

TS – Two Midlands purple sherds were examined petrographically; no specific traits were identified.

Fabric definition (macroscopic to x20) – All the Ticknall Midlands purple seemed similar in that it was regularly associated with relatively well-sorted quartz of about 0.50mm, some of which seemed quite angular, and irregularly scattered, the latter perhaps denoting relatively poor clay mixing. The presence of some interleaving of clays also suggested the latter. Despite the possibility of using a relatively iron-poor clay the final colour when high fired was still the typical purple.

Other diagnostic criteria (macroscopic) – Very little of this material has so far been published as the more highly decorated Cistercian-type wares have so far attracted far more attention. For instance, while reporting on large quantities of kiln material, only very limited references to this type have been made by Spavold and Brown (2005), and only a single form was illustrated for Peat's Close (*ibid* 95, fig 30). Usefully more Midlands purple forms have recently been published by Boyle and Rowlandson (2006–8, 51–6) suggesting that a fairly standard range was produced, though this makes its visual differentiation from other production centres more problematic.

Overall comparison with other production centres based on fabric

The visual qualities of the Ticknall Midlands purple fabric were not generally that distinctive from other Midlands purple. Though when highly fired it took on the typical purple colour of the type, there were indications that the clay was not as iron-rich (eg sample 70-18) as others included in this project; for instance, some Nuneaton seemed to indicate a similar trait (51-12). Ticknall Midlands purple can have interleaved clays of different colours, a characteristic shared with Wednesbury. Therefore generally Ticknall Midlands purple exhibited aspects shared with much of the other Midlands purple. However, the Ticknall Midlands purple generally contained larger quartz (0.50mm) which was present in moderate to common quantities, when compared with the other Midlands purple, and this seemed its most distinctive trait.

7.5.2 Comparative criteria for identification of wares by fabric-type (macro-/microscopically) at consumer sites

The following is a list of the potential criteria which have emerged as the possible main distinguishing features in terms of fabric when seeking to differentiate similar-looking wares from different production centres. In some cases there are inherent properties though in other cases a process of elimination is required; clearly the latter is less desirable, as it does not entirely rely on intrinsic qualities (for fuller descriptions see Appendix 2):

Cistercian-type wares

Wednesbury (2 fabrics) – (fabrics A and AE) the one (A) a very fine paler red or grey fabric, with little visible quartz and typically shows pale flecking; occasional fine white sandstone, and the other (AE; high fired) purple with a similar composition with additional sparse quartz up to 0.50mm;

Burslem (4 fabrics) – (fabrics E, F, G, H) very variable production which can be coarser with sparse quartz up to 0.50mm (F, G), but also included a very fine pale fabric (E) without visible quartz and a very fine pale red fabric (H) with larger quartz (0.25mm);

Nuneaton (2 fabrics) – (fabrics K, L) fine paler red or purple (high fired) fabric with abundant just visible quartz and sparse to moderate larger quartz up to 0.25mm; occasional fine white sandstone;

Ticknall (1 fabric) – (fabric AC) very fine medium red or grey/purple (high fired) fabric with little visible quartz.

Some of the Wednesbury, Burslem and Nuneaton products looked very similar to each other in general fineness; Nuneaton and some Burslem were noticeably coarser.

Midlands purple wares

Wednesbury (3 fabrics) – sometimes common quartz (fabric B) and sometimes little quartz (C and D), otherwise generally there are more dark/deep red iron-rich inclusions up to about 1mm (especially fabrics B and C) than other fabrics though similar inclusions also occur in other Midlands purple fabrics;

Burslem (2 fabrics) – (fabrics I and J) common/abundant 0.25mm quartz ie very similar to Nuneaton and smaller than for Ticknall;

Nuneaton (2 fabrics) – (fabrics M and N) the quartz is abundant and 0.20–0.25mm ie similar to Burslem (but some up to 0.50mm);

Ticknall (1 fabric) – (fabric AD) moderate 0.50mm quartz is larger than for other centres.

7.5.3 Comparison of production centre fabrics with consumer site fabrics

Bordesley Abbey Cistercian-type ware

It proved possible here to identify by eye a principal Wednesbury fabric (A). Comparison with the ICPS data suggested the refinement of the original Wednesbury fabric (A) and it was possible to subdivide the original fabric A and define a second fabric (AE). This second fabric did correspond with PCA group B; this then enabled more of the Bordesley to be identified to fabric (as fabric AE). Also one Bordesley sample (101) could be assigned to Ticknall in the light of the ICPS results, as it corresponded to a Ticknall Midlands purple fabric in appearance. However, two sherds (fabric X) remained unassigned visually to a corresponding production centre, and these were both highly vitrified and with no visible inclusions.

Austin Friars Leicester Cistercian-type ware

Visually the Leicester Cistercian-type was identifiable as either Ticknall or Wednesbury, and mainly the former – all very fine fabrics. This accorded well with the scientific data, in particular sample no. 75 being identified to Wednesbury by all methods. In the case of sample no. 77 a visual identification of its being a Ticknall product was negated by its assignment by ICPS as belonging to PCA group C. Otherwise there was a perfect correspondence between the ICPS and visual identifications.

Austin Friars Leicester Midlands purple

In practice it was not possible to positively assign on fabric-type any of the Leicester Midlands purple to any of the production centres in this survey; though the majority approximated visually quite closely to the Ticknall fabric, their generally iron-poor clay did not seem such a good fit. This conclusion is to some extent led by the ICPS which grouped these samples together but was not able to indicate a production area, but suggested that it might well be on similar geology to the Nuneaton material.

7.5.4 Characterising, comparing and identifying the products of the various production centres – some conclusions

Any conclusions about the comparative identification of differently sourced Midlands purple and Cistercian-type wares based on the results of this project need for the present to remain highly provisional, as the extent of analysis has been fairly limited in terms of sample size. In some cases very little is known or published about some of these production centres (eg Ticknall), whereas others have been published some years ago in quite an abbreviated fashion given the scale of excavated material (ie Chilvers Coton). In the case of Wednesbury there has more recently been a great deal of evaluation work and some excavation has followed (eg in 2006–7), but then the progress to publication has been slow (ie assessment by Edgeworth *et al* 2009); however the outcome of this work would still be the first comprehensive study of Cistercian-type from Wednesbury, and it may well shed more light on the characterisation of this ware type than has been possible in this study. It is hoped that archaeological work at this important centre will continue forthwith into full analysis and publication. However, for the moment the amount of information and its quality varies between the production sites and this project should only be regarded as a first step towards establishing an overall perspective on this material.

The ICPS results in particular, however, have wholly succeeded in differentiating the various production centres, and have, in addition, therefore, led to being able to suggest positive identities for all the sherds from the two consumer sites, even when this was not always associated with a provenance (ie much of the Leicester Midlands purple). The results of the petrographic work has confirmed that this type of analysis has relatively little to directly contribute towards identifying these ware types, though it has revealed that the Nuneaton wares do include occasional igneous rock which distinguishes pottery from this source from the other production centres in this survey, though its rarity renders this less useful for the purposes of practical identification.

The consistency of the ICPS data in grouping the pottery has enabled a concerted effort to be made using the visual/microscopy criteria to differentiate the different production centres (see above). The limited number of samples, however, leaves some considerable uncertainty about how valid any such characterisation is, but on the basis of the available ICPS evidence it would seem to have some credibility, and is, therefore, a foundation to build on for the future, especially as in some cases a good correspondence was achieved in the identification by eye of the consumer site pottery to fabric (both Ticknall and Wednesbury wares).

It is important to remember that the project is a pilot study, and one which has clearly necessitated a considerable degree of flexibility with regard to the detailed approaches and outcomes compared to the theoretical framework set out in the PD. As a result it was not always possible to access the material we ideally desired for the scientific testing.

8. Conclusions

Late medieval/transitional wares: the ceramic perspective prior to the project

Midlands purple and Cistercian wares are some of the commonest wares on transitional, late medieval–post-medieval sites and are widely used as a chronological indicator. Production took place at a number of centres in the west Midlands from the 16th century (and it is presumed in the 15th) until the late 17th century when Stoke-on-Trent (Staffs) effectively overwhelmed its competitors. Yet the early years of this major ceramics industry with its new pottery types are not understood, neither when nor where the earliest production took place, or its market area. Despite sizeable deposits of wasters from a number of west Midlands production centres, commentators have continued to highlight the fact that excavation of these potteries has failed to provide convincing dating evidence for the inception of the industry, or make it possible to distinguish the potteries' products and thereby to link traded wares back to production sites (eg Boothroyd and Courtney 2004, 94–6; MPRG meeting at Sharpe's Pottery Museum, in Swadlincote on 27 October 2007).

There are potentially several key excavated consumer sites in the region with stratified early material (pre-Dissolution and Dissolution-dated material), and two were identified as a test case for this pilot study, one to the south-west of and the other to the north-east of Birmingham. The ceramics from both the monastic houses of Austin Friars Leicester, and Bordesley Abbey (Redditch, Worcs) – purchased at fairs and markets or from itinerant traders – are likely to have originated from more than one production centre, as at both sites visual variation in the fabrics of the wares had been recorded (for summary see Appendix 1, and Table 2). At Bordesley, four distinct fabrics were identified among the Cistercian-type ware vessels. At Austin Friars Leicester four variants of Midlands purple ware had been identified (Woodland 1981). David Barker (pers comm) had suggested that one of the Bordesley Cistercian-type fabrics resembled the material produced at Stoke, and another one, some of the Ticknall Cistercian-type products. Anne Boyle, Sue Brown, Janet Spavold and colleagues had suggested that Cistercian-type ware that appears typologically (form and decoration) identical to material collected from Peat's Close Ticknall is identifiable at Austin Friars Leicester in phase 9A, associated with Church Lane Ticknall style Midlands purple ware and, similarly, that Midlands purple ware vessels reported from Austin Friars Leicester were typologically similar to forms from Church Lane (Austin Friars phases 7A and 9A) and Peat's Close (phase 9A) and were supplied from there (Boyle 2002–3, 116; Spavold and Brown 2005, 43, 93, 95–6; Boyle and Rowlandson 2006–8, 58). Given the proximity of Chilvers Coton Nuneaton, to both these consumer sites, it was also anticipated that Nuneaton products would have reached one or both. However, prior to this project none of these suggestions had been corroborated by scientific fabric analysis.

Late medieval/transitional wares: the ceramic perspective developed during the project

Characterising Cistercian-type and Midlands purple wares produced across the west Midlands using scientific analysis has been the core of this project, as the essential first step in any attempt to address the wider issues such as chronological development and distribution patterns. These wares are visually difficult to distinguish and few vessels on consumer sites can be confidently attributed to a production centre, although researchers have attributed particular decorative motifs or visual characteristics to a manufacturing location.

The establishment of chemical signatures (by inductively coupled plasma spectrometry [ICPS]) for the various production centres has succeeded in separating out the different centres demonstrating that this line of analysis is potentially very effective for discriminating between the various centres, and even between Cistercian-type and Midlands purple wares from the same centre. The application of thin section petrography has not resulted in particularly useful information for the same purpose, but this was to some extent to be expected given the nature of the pottery fabrics being investigated.

The key part of the project was to relate the scientific work to the visually observable characteristics of the fabrics. As a pilot study this project was not able to encompass the whole gamut of ceramic attributes, in particular typology of forms, decoration and glaze colours. The independent visual examination of the pottery fabrics defined 30 fabrics from 109 samples representing the eight production lines showing that there was a considerable degree of variation in the clay matrices used. This suggested that the very small number of samples used could well have omitted other fabrics and also that it was difficult, given such variation, to define the range of fabrics: that is, it was uncertain, looking at such small numbers, whether any variation was within a fabric-type or whether it amounted to different fabric-types. A further difficulty would be if there was no pottery in the selected consumer site samples for some of the production centres, then the exercise in matching could not be put to the test, and the ICPS data analysis did indeed show this to be the case (eg for Burslem).

Setting these difficulties aside it was felt that some considerable headway was made with defining fabrics which were distinct enough and could be assigned to specific centres by visual examination, and this was particularly the case for Wednesbury Cistercian-type ware and Ticknall Midlands purple. Not surprisingly these were fabric-types that were also numerically well represented in the samples from production centres suggesting they were potentially more consistent types that might then be expected to be traced to consumer sites. However the results even here were not entirely clear-cut, for though Ticknall Midlands purple fabric was visually recognised from Austin Friars Leicester, a lot of other material was also visually assigned to this type whereas, according to the ICPS results, this is a group that is similar to Nuneaton, and, therefore, still remains unidentified to a specific source. Previously links between Ticknall products (both Cistercian-type and Midlands purple wares) and Austin Friars Leicester had also been suggested on typological grounds (eg Boyle and Rowlandson 2006–8, 58); in the case of the Midlands purple ware this typological attribution to Ticknall may now be usefully revisited in the light of these ICPS results.

Even where fabrics could not be visually identified to a specific production centre the results of the project potentially allow some centres to be eliminated from consideration due to the recognition of their relatively more distinctive fabric character (Ticknall Midlands purple being consistently coarser in fabric) compared to others. This may allow the development of a system of multi-centre attributions and lead to selective ICPS analysis which could be interpreted against the background of data from the present project. Accordingly this report contains all the technical supporting evidence including numbered and tabulated ICPS plots (Figs 2–7). Hopefully this availability of extensive data will stimulate more analysis being undertaken.

This project has followed a proven methodology. An ICPS-based analysis of a very similar group of material, post-medieval tin-glazed fine wares and tiles produced at several centres in London, where styles were widely imitated and potters moved between pothouses, proved to be a very successful characterisation exercise, in that it identified the products of individual manufactories, with much wider implications for the industry as a whole and future work (Hughes 2008). The results for Cistercian-type and Midlands purple wares seemed to be equally successful, again demonstrating the extreme effectiveness of this technique for distinguishing relatively homogeneous wares emanating from many centres, where at the same time the minutiae of variation are not presently understood. Taking several centres together has allowed the variation that is very apparent in the fabric-types to be defined, not only in terms of their inherent qualities but also in terms of differences from each other which adds a further level of distinction, and, for the purposes of regional studies, this is potentially important. When working with samples from production centres this has given us the ability to define various fabric-types which, on the face of it, were entirely plausible as the products of different centres. The application of these fabrics to sorting material from the two consumer sites resulted in a reasonable level of success in terms of the visual identification of fabrics to source. However, greater confidence was instilled where the visual results coincided with the groups established by ICPS analysis where the latter could be most clearly determined to an identifiable source.

There was less apparent success where the ICPS itself was not able to determine a likely source (ie all the Leicester Midlands purple), as much of this pottery was assigned visually mainly to Ticknall, which seems to contradict the ICPS designation of 'similar to Nuneaton '. It was ironic that a high proportion of the consumer site samples (ie Austin Friars Leicester Midlands purple) turned out to sit outside the production centres included in this project, as this limited the opportunity to demonstrate matching of material between consumer and production sites. It was indeed very surprising that no Nuneaton material was positively identified at Leicester or Bordesley Abbey given the apparently huge scale of production. However, given that the Leicester Midlands purple was a consistently distinct group it must raise the interesting possibility of an (as yet) unknown major production centre, although it cannot be discounted that this was a sign of the overall project sample size being too low to represent fully the range of types from each of the known major production centres in the region.

Late medieval/transitional wares going forward

In the case of those production sites situated in modern urban contexts it is likely that much more will come to light in the course of future archaeological work carried out as part of the development process, but there is also currently an inability to deal effectively with large quantities of this material, as our ability to sort and record it in a rapid and efficient way has not been fully developed. Part of such development would consist in having a clear definition of fabrics and forms to facilitate sorting and the capture of data; the expense of dealing with any new kiln groups would then be minimised so that resources could be focused on the better publication of key material. Hopefully this project will have contributed to helping with this situation by providing a better definition for fabric distinctions for use on consumer sites as a foundation for the gradual accumulation of data for further characterising this material. It has done this by emphasising the fabric integrity of material from their respective production areas, even where they were market centres (eg Wednesbury), and by pointing out where fabric differences do exist between centres as well as fabric overlaps between centres, where special caution is needed. At the least this has established some of the salient points which could assist future researchers in this area.

It is very important that attention is also turned to forms (and surface treatments and glaze) in order to complement the current work on fabrics. This necessitates a programme of publishing a complete range of forms, especially for those production centres (eg Wednesbury and Ticknall) where this aspect is currently under-documented given the evident scale of production and the amount of material that has now been excavated in more recent years. As more material is published form-based criteria will become much more important for the differentiation of products from different centres, and may hopefully overcome some of the present difficulties that have been encountered by approaching this material solely through their fabric-types as in the present study.

9. Other dissemination

A note on the then ongoing project was published in the MPRG newsletter in 2009, and a further short report is intended to be published here.

10. Recommendations

General – archives

The difficulty in locating major archaeological archives in museums highlights a need for better tracking and identification of archaeological archives, and the potential value of a national database of archaeological archives. The difficulties we experienced in gaining access to material were often exacerbated by the location or method of storage (due to heavy demands on storage space) and on occasion by insufficient knowledge on the part of collections managers of the archives, their structure and archaeological context, and of their value to the archaeological community as a research resource, suggesting that curation of archaeological archives in regional centres rather than locally would actually improve access for users. Region-wide studies like this one, which are all too rare, could then be easier to carry out.

General – geology

The broad national mapping of the raw natural materials used for ceramic manufacture has been undertaken by the British Geological Survey and productive uses are briefly considered during their reporting, but there has been no detailed chemical work on clays as such material is considered of little economic value, apart from where historical pottery production sites have occasionally been studied holistically in their ceramic landscape and ecology (eg at Bordesley Abbey; Hughes 1993).

Being an extractive industry there is always the possibility that potting clays have been totally exhausted but in the case of the major industries studied here the exploitation of very major geological deposits (usually the Carboniferous Middle/Upper Coal Measures) was the norm. Though the present archaeological study is not dependent on such data for its interpretation of locally sourced products, the availability of such data would considerably enhance the conclusions drawn from the ICPS data in particular. Consideration might, therefore, be given to the establishment of a database of such data derived from local clays for reference during future studies of this kind. Such data may be of importance as much for intra-centre, as for inter-centre, resolution where production centres covered large areas.

The present petrographic study has, however, confirmed the relative limitations of petrography (clay body and glaze) for these fine-grained highly fired ceramics, both coarse (Midlands purple) and fine (Cistercian-type) wares, given the nature of the fabric matrices used.

Inception of Cistercian-type and Midlands purple industries

Though this project was not specifically addressing the question of the first production of these wares it has confirmed the presence of Wednesbury (ICPS PCA group C) and Ticknall (1) Cistercian-type wares at Austin Friars Leicester in pre-Dissolution deposits of phase 7A, whereas the Midlands purple in the same phase and later (latest pre-Dissolution; phase 9A) was derived from elsewhere. At Bordesley Abbey Wednesbury (ICPS PCA group C) and Ticknall (1) Cistercian-type wares were also confirmed, and here these were supplemented by ICPS PCA group B-unknown, and all were associated with pre-Dissolution and later deposits. With the greater definition of these wares at consumer sites it may well be possible to inject much greater precision into our understanding of their earliest development and so establish where the first production of this material occurred in the region.

Distribution of Midlands Cistercian-type and Midlands purple wares

The results of this project suggest that distributions may not be readily predictable based simply on distance from markets (ie the apparent absence of Nuneaton wares from Austin Friars Leicester). Clearly visiting more collections with consumer site assemblages, such as assemblages from Coventry and Warwick, would be helpful with specific regard to the Nuneaton question, but generally the establishment for the first time of the presence of Wednesbury and Ticknall wares at Bordesley needs to be followed up with the investigation of late medieval collections throughout the west Midlands, though this would be best undertaken following further definition of source for the ICPS-defined PCA B group and Midlands purple group from Austin Friars Leicester.

In the course of collecting samples, Burton Dassett (Warks; Palmer 1987, and Bond 1982) was identified as another very suitable consumer site, most especially as its geographical location offers the prospect of identifying where Nuneaton material went (so far none of this has been located at consumer sites) and it is from a well-dated (pre-1500) excavated sequence relating to a secular market centre (though unpublished). In general late medieval/transitional wares from such well-dated contemporary deposits are considered to be rare in the west Midlands.

Such an extended survey should particularly include the investigation of places with largely unpublished major assemblages such as at Nottingham, but should also include a survey of published reports (eg Derby; Coppack 1972).

Other production centres?

The results of this project have raised the possibility of other centres supplying Cistercian-type and Midlands purple wares to the west Midlands region (eg the Midlands purple dominating the Austin Friars Leicester assemblage). Difficulties in acquiring samples at the outset of the project may have contributed to greater uncertainty in this regard, since possible production centres in Jackfield (south Shrops) and possibly at West Bromwich (south Staffs) were omitted. The final inclusion of these possible production centres would quickly serve to consolidate the results of this project by expanding the current dataset and so determine whether these were the missing centres indicated by pottery so far not located to source by the ICPS study. The present project has also, however, raised the possibility that to the east of the west Midlands region another major supplier of Midlands purple may yet to be located.

Midlands Cistercian-type and Midlands purple wares characterisation – the future

Using the foundation provided by the data gathered within this project on clay/fabric there is next a need to systematically establish a west Midlands typology of forms and decoration, identifying where these can be taken as being diagnostic of, or restricted to, certain production centres/sites. The aim would be to characterise individual centres/sites as far as possible. As part of this strategy it is proposed that the following should be undertaken:

a) the development of detailed typologies of forms and decoration for the different production centres – by examining potential links between fabrics and forms/decoration as a means of distinguishing production centres and products, by recording pottery from consumer sites to begin to define the market areas of the major west Midlands late medieval production centres, and by exploring potential links between the precursors of Midlands purple and Cistercian wares, and those wares themselves and their respective date ranges – in order to inform the wider understanding, in a period of general ceramic transition, of the chronology and beginnings of this major industry, in the region and beyond, since potteries throughout Yorkshire and the Midlands manufactured similar wares;

b) the comparison of the characterisation data from Midlands purple and Cistercian-type wares stratified in pre-Dissolution (pre-1538) and Dissolution-period contexts from the two domestic consumption sites in this pilot study – Bordesley Abbey (Worcs), and Austin Friars Leicester – with other uniquely early and securely-dated material (eg from Burton Dassett) using the same characterisation data as for production sites, and including late medieval/transitional wares, the precursors and/or contemporaries of Midlands purple, as well as Midlands purple and Cistercian-type wares from these sites, in order to provide firm dating for the use of these wares and firm indicative *taq* dates relating to the inception of (at least some areas) of the industry; and, thereby, provide indicative dating based on these most ubiquitous of wares, at the same time highlighting any remaining dating relating to these wares;

c) the formulation, thereby, of a preliminary interpretative model which can be tested and revised with the addition of new data,

   and;

d) most importantly, to encourage the use of the publicly accessible data established by this project for the west Midlands production centres/sites by historic environment professionals and others across the region in their response to both existing collections and to new material from production and consumer sites, and so ensure efficient use of resources; and to exploit and regularly build on these data and the model by future analyses of ceramics in this region and beyond.

11. The archive

The archive comprises the following:

a) collection of sampled sherds, which is now incomplete as some have been completely consumed during the analysis;

b) sample records (paper records), and;

c) descriptions of fabrics (paper records).

12. Acknowledgements

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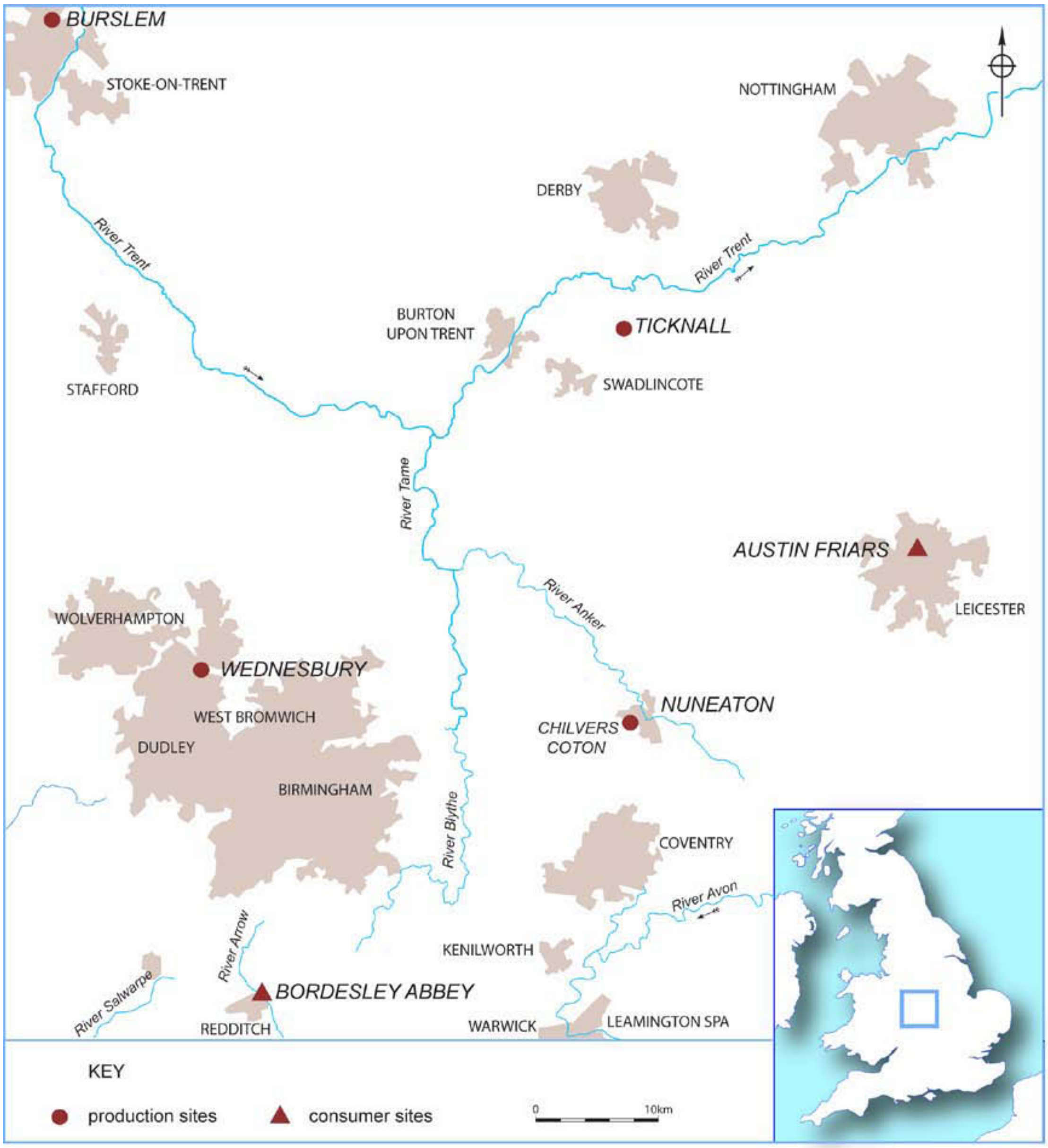


Figure 1 Location of Midlands purple and Cistercian-type wares production in the west Midlands, with consumer sites included in this project shown. Main rivers only indicated

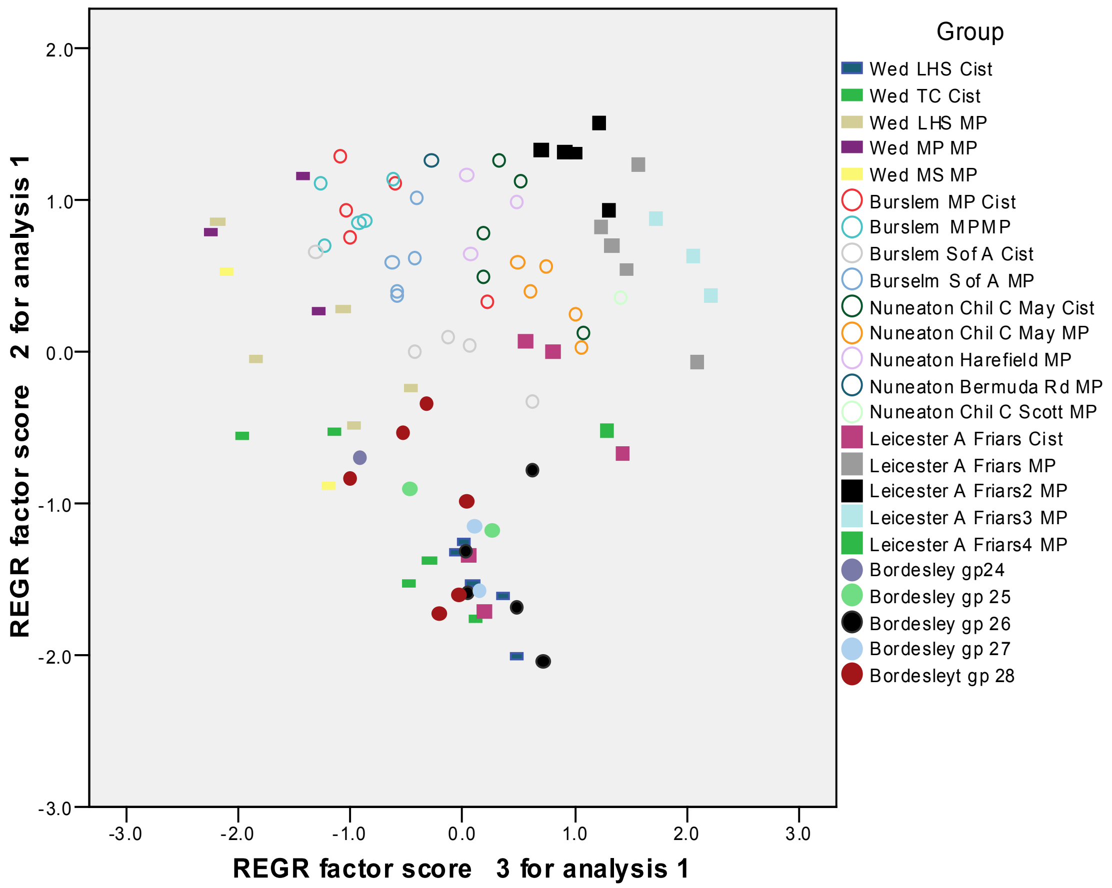


Figure 2a

Note: all the figures are pasted into this document as Windows metafiles. The SPSS statistical program automatically lists all the symbols for the pottery groups on the right, including those groups omitted from the PCA. In practically every figure, only the pottery included in the PCA has filled-in symbols, or else (as in Fig 2) those which showed significant patterns which were highlighted.

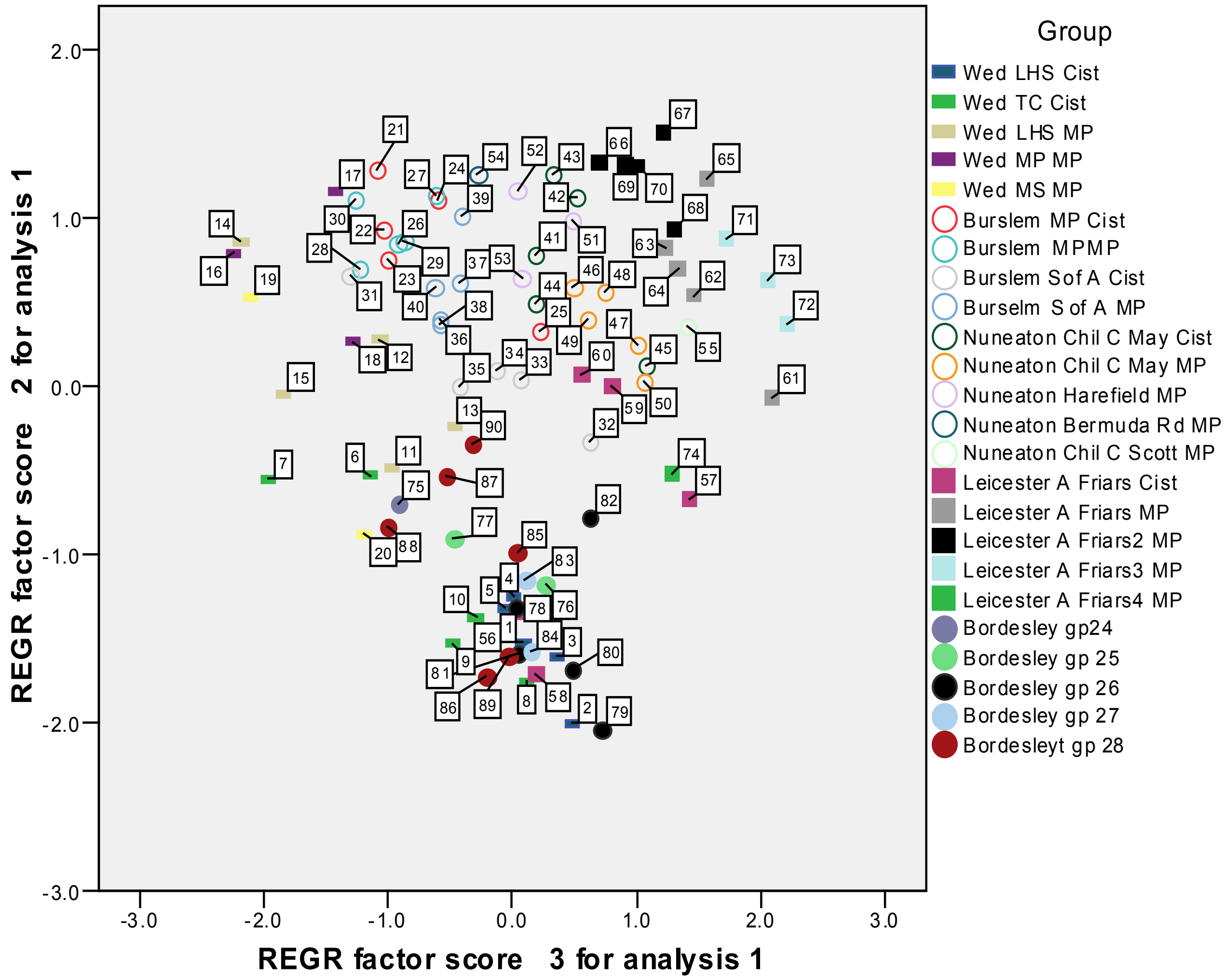
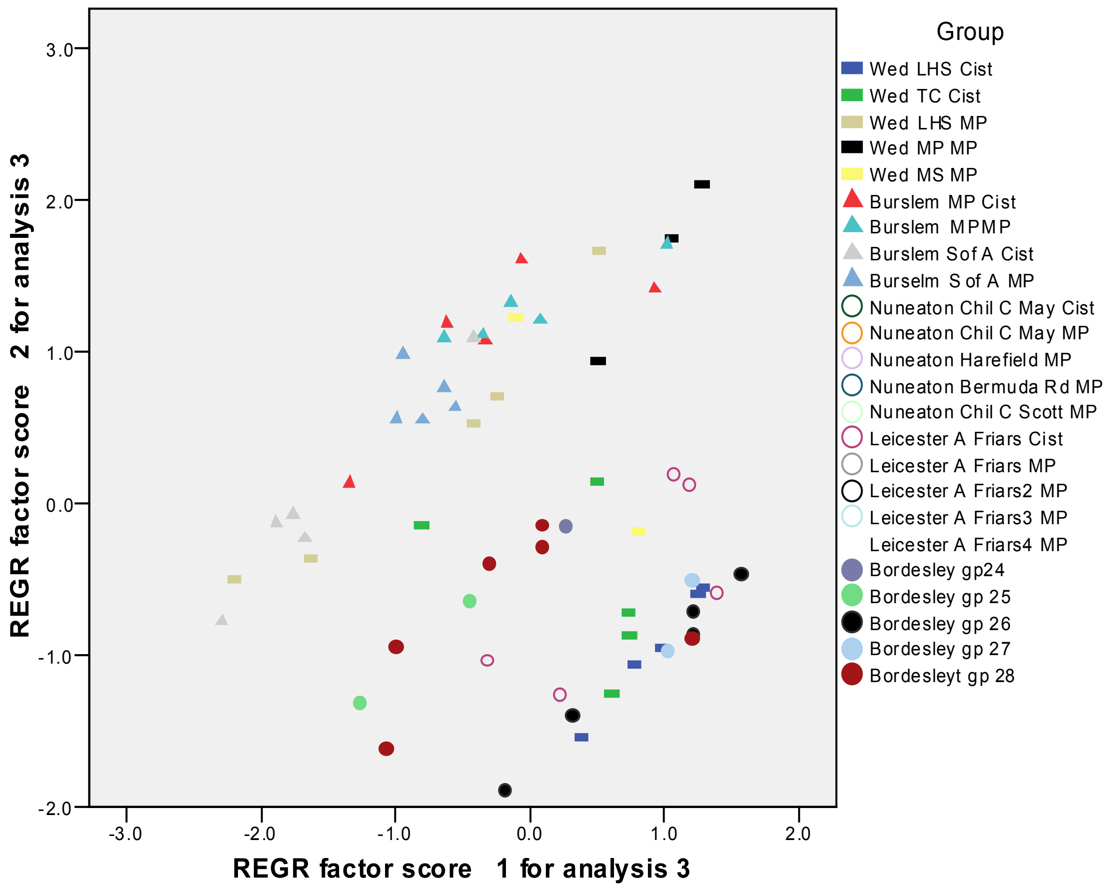


Figure 2b (for conversion of symbol numbers to project sample numbers see relevant table in Appendix 3)



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Group
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Wed TC Cist
Wed LHS MP
Wed MP MP
Wed MS MP
Burslem MP Cist
Burslem MPMP
Burslem Sof A Cist
Burselm S of A MP
Nuneaton Chil C May Cist
Nuneaton Chil C May MP
Nuneaton Harefield MP
Nuneaton Bermuda Rd MP
Nuneaton Chil C Scott MP
Leicester A Friars Cist
Leicester A Friars MP
Leicester A Friars2 MP
Leicester A Friars3 MP
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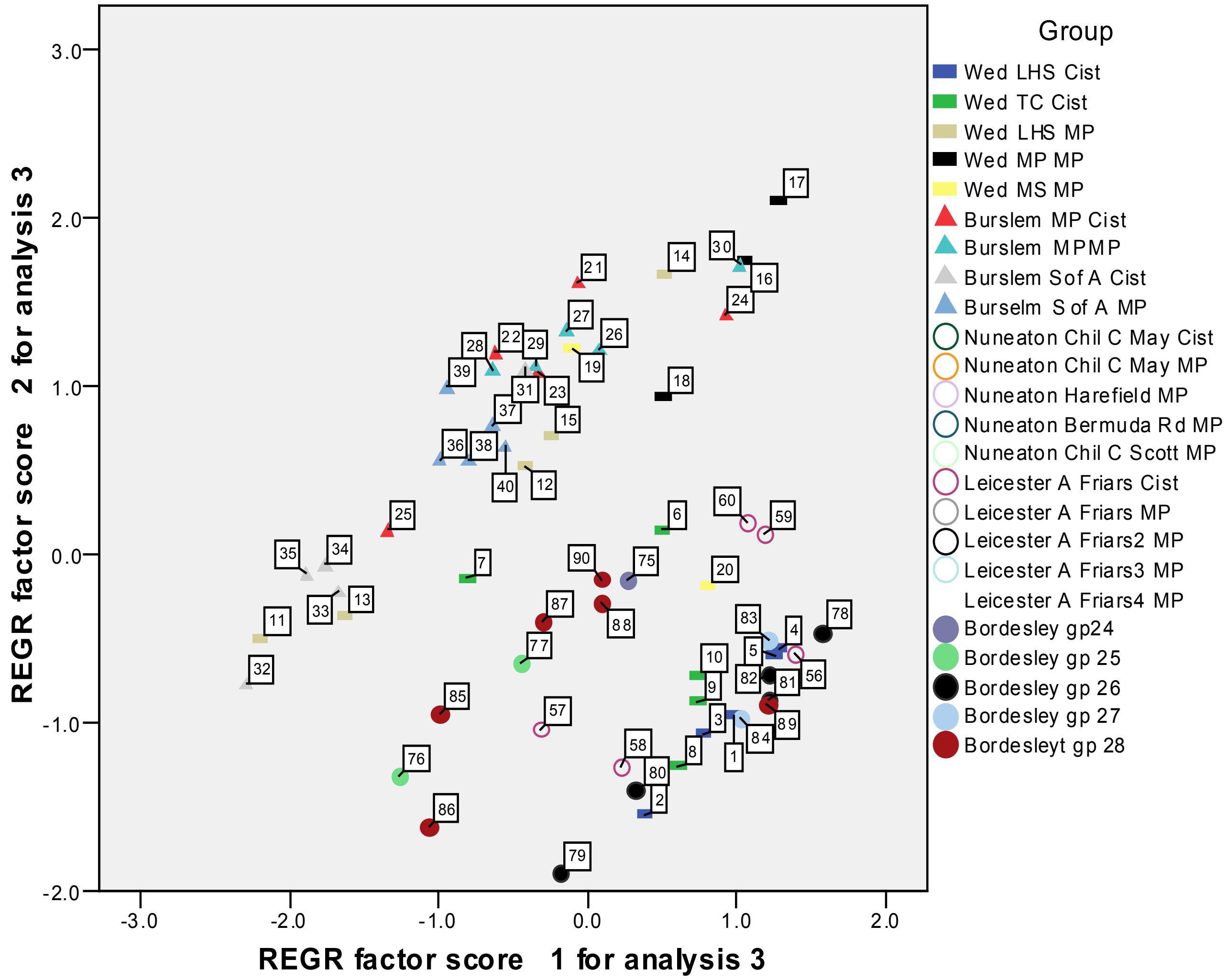
Bordesley gp 27
Bordesleyt gp 28

Figure 3a



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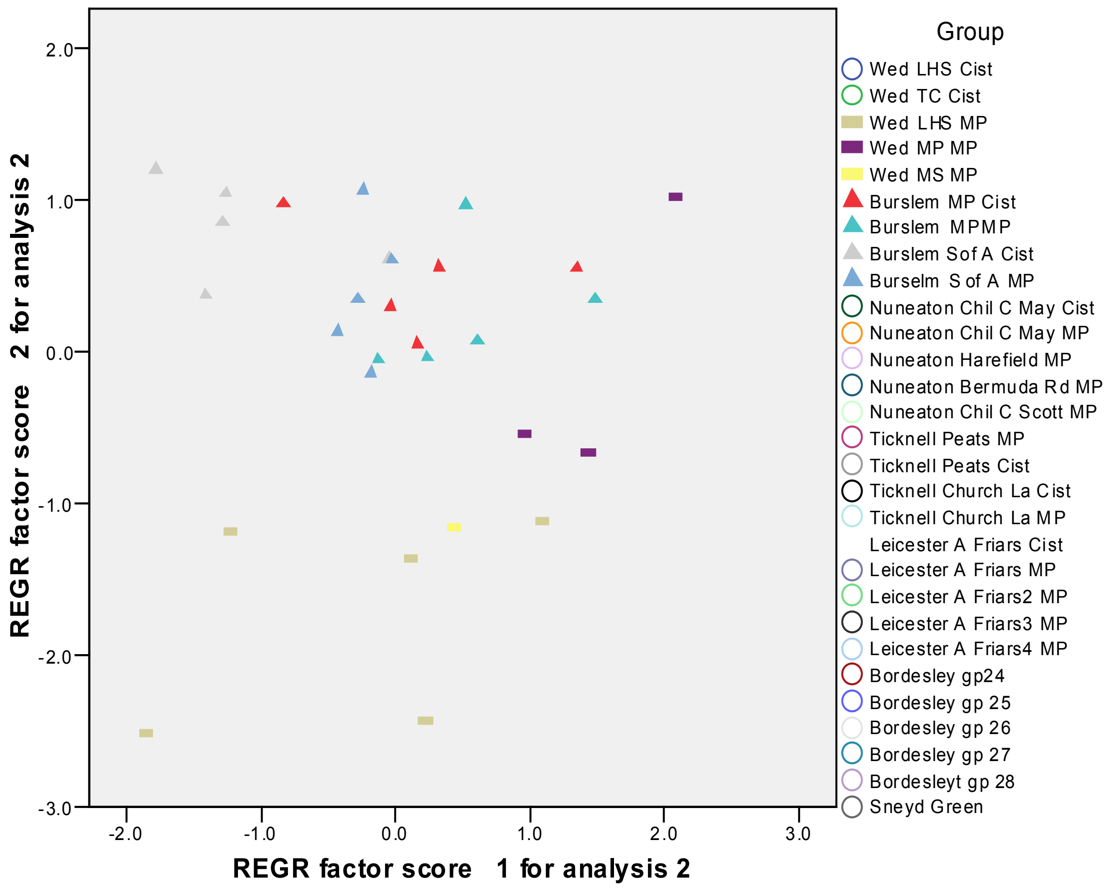

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Wed MS MP
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Burslem MPMP
Burslem Sof A Cist
Burselm S of A MP
Nuneaton Chil C May Cist
Nuneaton Chil C May MP
Nuneaton Harefield MP
Nuneaton Bermuda Rd MP
Nuneaton Chil C Scott MP
Ticknell Peats MP
Ticknell Peats Cist
Ticknell Church La Cist
Ticknell Church La MP
Leicester A Friars Cist
Leicester A Friars MP
Leicester A Friars2 MP
Leicester A Friars3 MP
Leicester A Friars4 MP
Bordesley gp24
Bordesley gp 25
Bordesley gp 26
Bordesley gp 27
Bordesleyt gp 28
Sneyd Green
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REGR factor score 1 for analysis 2

Figure 4a

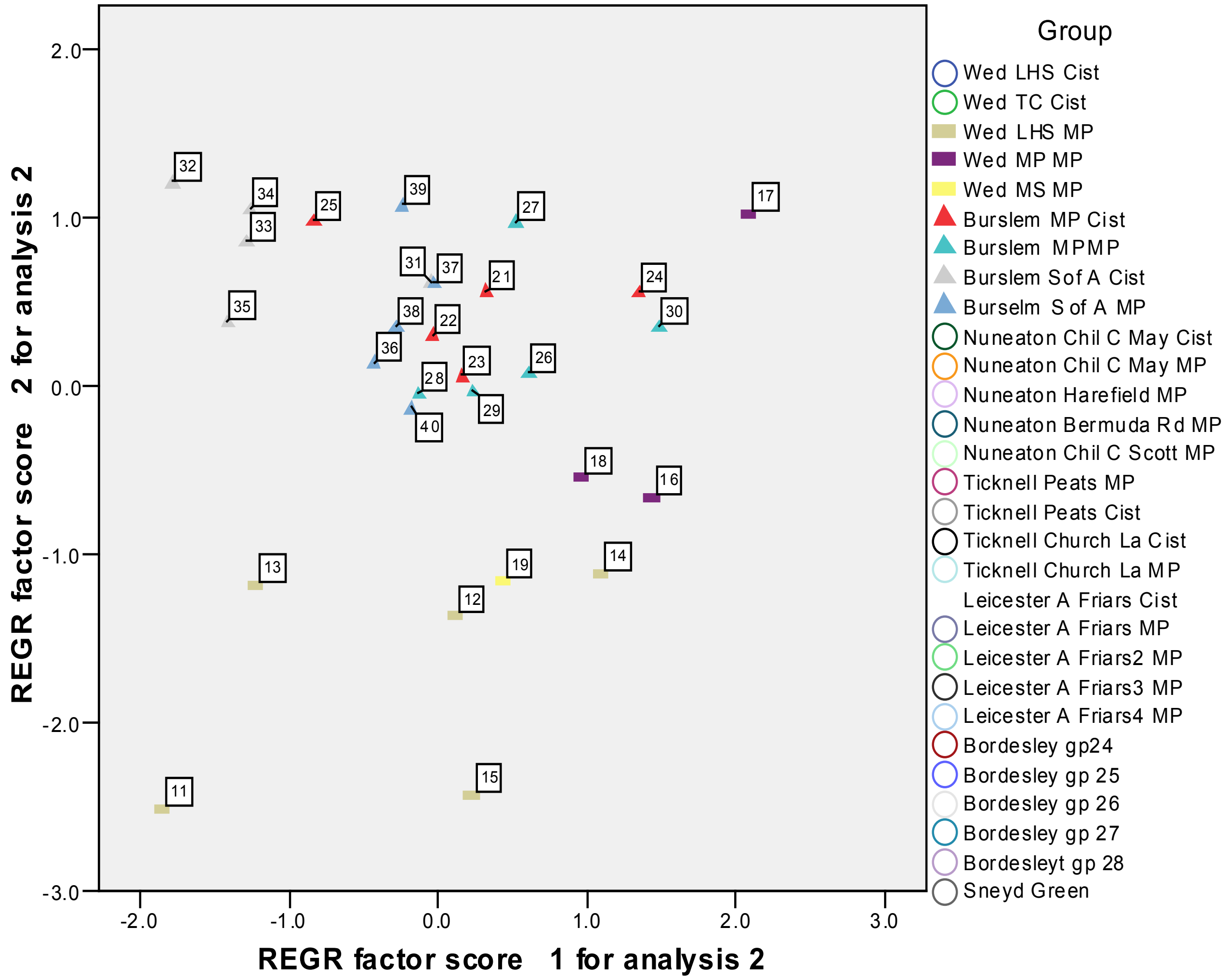
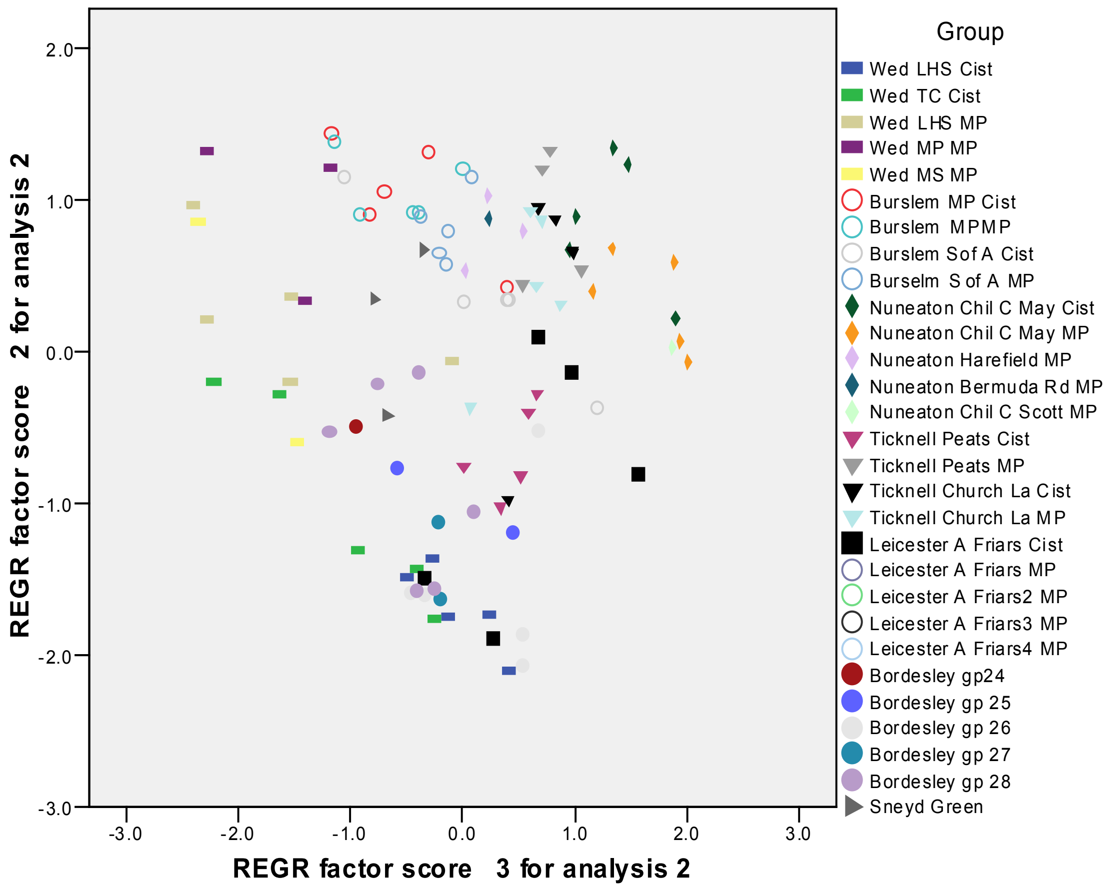


Figure 4b (for conversion of symbol numbers to project sample numbers see relevant table in Appendix 3)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Nuneaton Chil C May MP
Nuneaton Harefield MP
Nuneaton Bermuda Rd MP
Nuneaton Chil C Scott MP
Ticknell Peats Cist
Ticknell Peats MP
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Bordesley gp 26
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Bordesley gp 28
Sneyd Green
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REGR factor score 3 for analysis 2
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Figure 5a

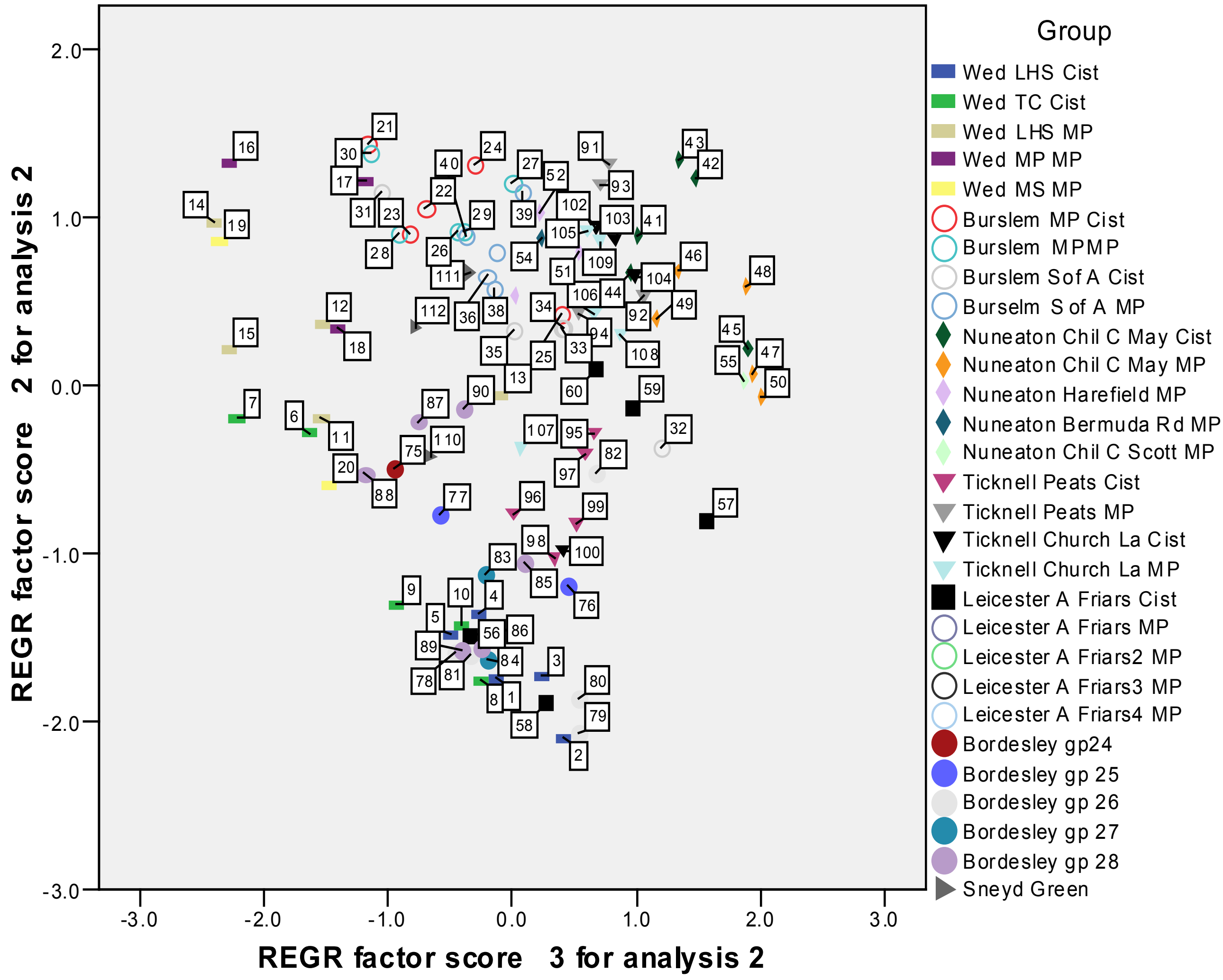
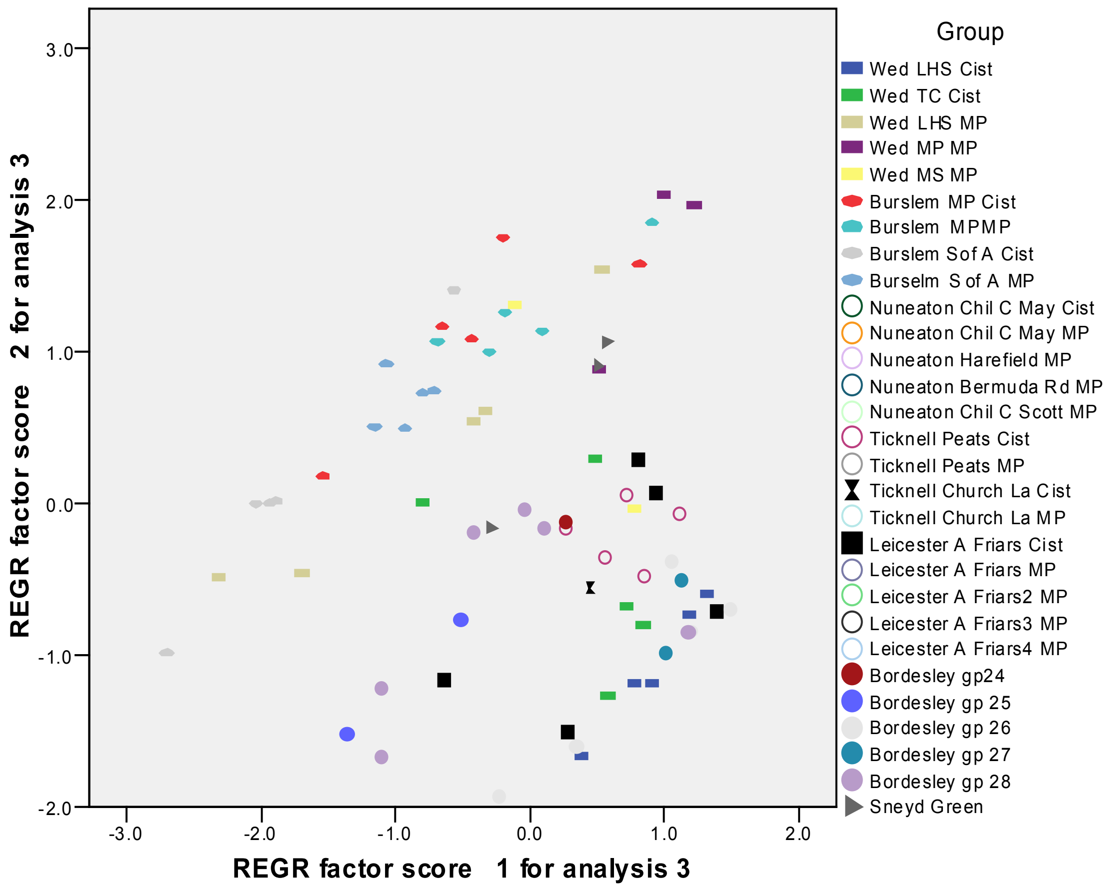


Figure 5b (for conversion of symbol numbers to project sample numbers see relevant table in Appendix 3)



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Nuneaton Harefield MP
Nuneaton Bermuda Rd MP
Nuneaton Chil C Scott MP
Ticknell Peats Cist
Ticknell Peats MP
Ticknell Church La Cist
Ticknell Church La MP
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Leicester A Friars3 MP
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Bordesley gp 27
Bordesley gp 28
Sneyd Green
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REGR factor score 1 for analysis 3
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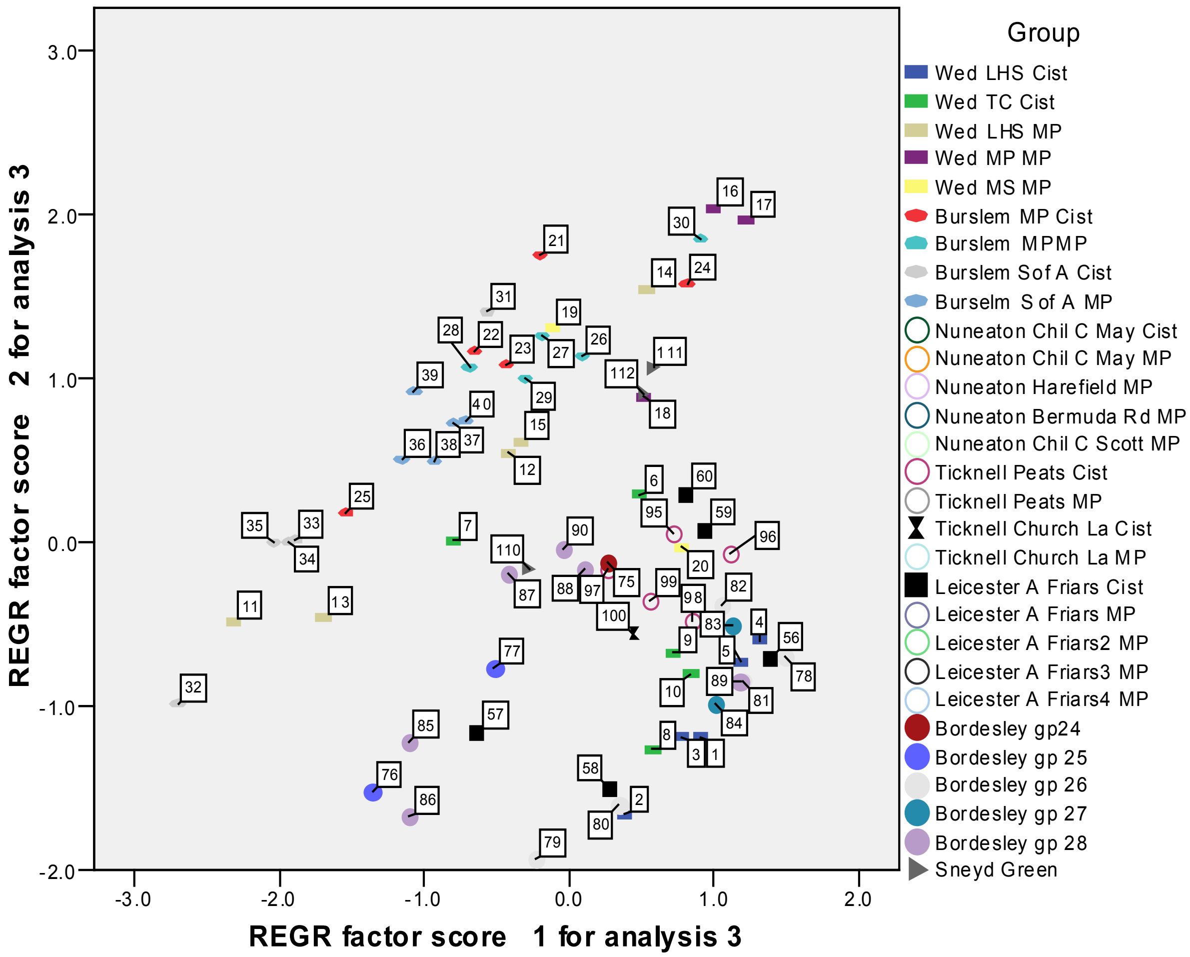
Figure 6a



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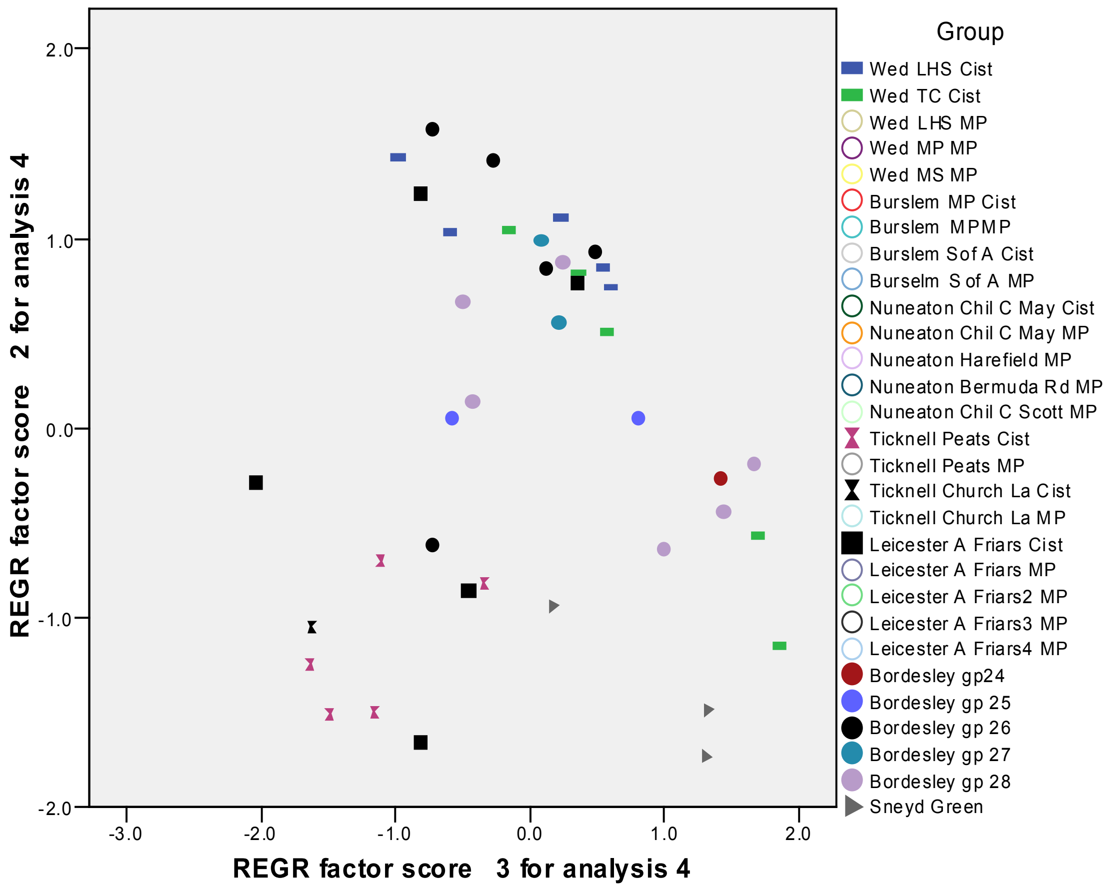
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Wed TC Cist
Wed LHS MP
Wed MP MP
Wed MS MP
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Burslem Sof A Cist
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Nuneaton Chil C May MP
Nuneaton Harefield MP
Nuneaton Bermuda Rd MP
Nuneaton Chil C Scott MP
Ticknell Peats Cist
Ticknell Peats MP
Ticknell Church La Cist
Ticknell Church La MP
Leicester A Friars Cist
Leicester A Friars MP
Leicester A Friars2 MP
Leicester A Friars3 MP
Leicester A Friars4 MP
Bordesley gp24
Bordesley gp 25
Bordesley gp 26
Bordesley gp 27
Bordesley gp 28
Sneyd Green
REGR factor score 2 for analysis 4
REGR factor score 3 for analysis 4
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Figure 7a

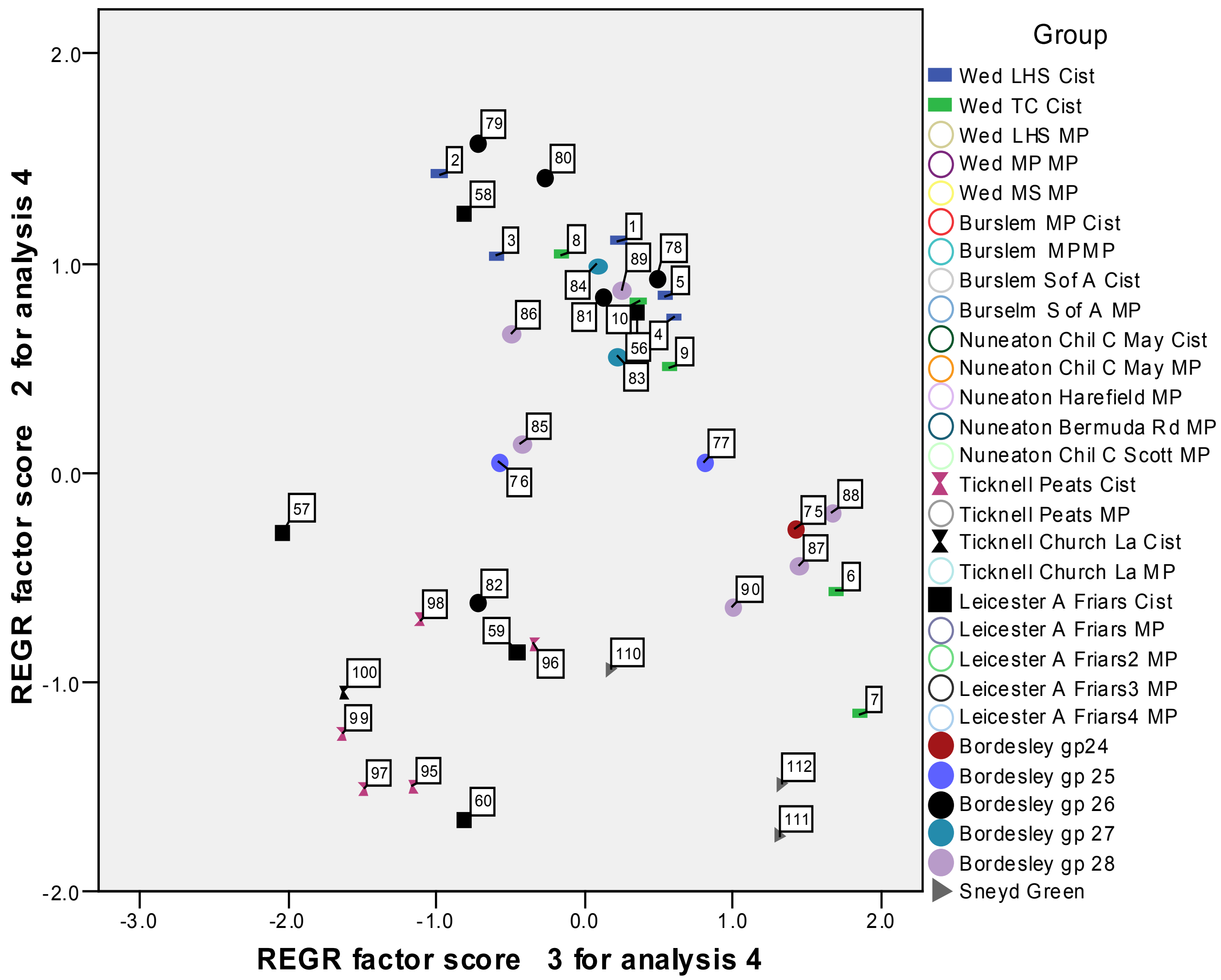

Figure 7b (for conversion of symbol numbers to project sample numbers see relevant table in Appendix 3)

Appendices

Appendix 1 Archaeological background to the consumer sites

Bordesley Abbey

Now part of Redditch and *c* 17 miles south of Birmingham on the east side of Worcestershire, this site has provided the initial impetus for this whole project. Exceptional preservation is the key to Bordesley's importance – the unusually deep and complex stratification (particularly in the abbey church and cloister, but also elsewhere throughout the precinct) has yielded an exceptionally closely dated and detailed sequence of activity and artefacts compared to material from other monastic sites. The material assemblages recovered are very well stratified and sit within a finely divided chronological framework. This is true of the exterior eastern cemetery where the archaeological stratification and the material assemblage from the area adjacent to the east end of the church can be related to the architectural remains and building history. The abbey church has an exceptionally well-preserved succession of floors and construction levels within the 2-metre high remains of its walls: seven separate floor levels and intermediate make-up and builders' layers, extending from the 12th-century preparatory building operations to the final floor and Dissolution destruction debris. Dissolved in 1538, the abbey church and claustral buildings were demolished but never built over. The archaeological stratification and material assemblage can be related to the architectural remains to give a detailed history of the building and its use in a way that is probably without parallel.

Bordesley Abbey has produced, particularly from the church and exterior eastern cemetery, stratified Cistercian-type ware and late medieval highly-fired orange ware very similar to Midlands purple (the precursor and/or contemporary of Midlands purple; cf Staffordshire 'late medieval orange wares', Ford 1995). There are very few sherds at all of classic Midlands purple from this site to date. The amounts of pottery from floors and make-ups in the church and main cloister, and from the eastern cemetery, are in general obviously less than one would expect from for example service areas. (The 1997 re-excavation of a 1960s trench in the south cloister range – principally the refectory – produced 107 sherds of Cistercian-type ware, but approximately three-quarters were from the 1960s backfill.) The numbers of sherds, taken with their context, from the church, east cloister walk and eastern cemetery are sufficient for and justify analysis. These areas are unpublished. The pottery has been classified in accordance with the Bordesley fabric type series (see Nailor 1993, 142–63) and catalogued, with input from a number of ceramic specialists; it was assessed as part of the recent post-excavation assessment (by Derek Hurst and Susan M Wright; Wright and Hirst 2006). The three wares of interest here are quantified in Table 2a, and their highly-fired precursors, on consumer sites: summary table of the context and quantity of the assemblages identified for analysis at Bordesley Abbey and Austin Friars Leicester. Cistercian-type ware occurs at Bordesley in primary Dissolution-period destruction levels (period 5), occurring with imports (eg, a Langerwehe white-ware horn), and in pre-Dissolution levels (periods 4B and 4C, early 15th to early 16th century); the hard-fired earthenwares very similar to Midlands purple are stratified in 15th-century and pre-Dissolution levels (periods 4A–4C, c 1400 to early 16th century) and later, Dissolution-period, levels (Wright and Hirst 2006; Bordesley Abbey archive).

Austin Friars Leicester

This site is situated in the south-west corner of Leicestershire, *c* 43 miles east of Birmingham but roughly halfway between two of our production areas, viz *c* 22 miles south of Ticknall and *c* 19 miles north of Chilvers Coton, Nuneaton. The major ceramics assemblage from the Austin Friars Leicester, also dissolved in 1538, derives, in contrast to that from Bordesley Abbey, from excavations outside the main cloister, in the area around the second cloister (Mellor and Pearce 1981). It is the site cited as 'exceptional' because of its large Dissolution-period assemblage of Midlands purple and Cistercian-type wares (eg Boothroyd and Courtney 2004, 95). Again, the three wares of interest here are quantified in Table 2b. Reported from Austin Friars Leicester are finds of 'transitional Midlands purple' fabric P(xviii), Midlands purple fabrics P(xix)–P(xxii) and Cistercian ware fabric from 15th-century contexts (phase 7A), particularly from the drain below the south range of the second cloister; and large quantities of Midlands purple and Cistercian ware from deposits accumulating in the south drain and north ditch (phase 9A) which were sealed by demolition rubble (Mellor and Pearce 1981, 35–45, 81–129). The date ranges suggested for earlier phases raise interesting questions for the pottery reported from those phases; the dating of mid 15th century suggested for the first occurrence of Cistercian ware is an example of this (Boyle and Rowlandson 2006–8).

Appendix 2

Fabric descriptions (*by* Derek Hurst)

Only a general colour is noted as a great deal of variation is often evident (Munsell colour codes are used, where available, but colours are described as seen). Fabric hardness, surface glazes and treatments are not described here. For full descriptions see the archive.

Production sites

Fabric A – Wednesbury Cistercian-type

Colour: pale red (5YR 5/8) throughout
Manufacture: wheel-made

Inclusion	quartz	quartz	white specks
Frequency	abundant	rare	rare
Sorting	well-sorted		
Size	very fine	*c* 0.1mm	*c* 0.1mm
Rounding			

Fabric B – Wednesbury Midlands purple

Colour: Red (10R 4/8) or reddish yellow (7.5YR 7/8) throughout
Manufacture: wheel-made

Inclusion	quartz	blue/red specks	creamy lumps
Frequency	common	sparse	rare
Sorting	ill-sorted	ill-sorted	
Size	up to 0.25mm	up to 1mm	up to 2mm
Rounding	rounded		

Fabric C – Wednesbury Midlands purple

Colour: yellow (10YR 6/8)
Manufacture: wheel-made

Inclusion	red pellets	glassy black specks	
Frequency	moderate	sparse	
Sorting	ill-sorted	ill-sorted	
Size	up to 1mm	up to 0.5mm	
Rounding			

Fabric D – Wednesbury Midlands purple

Colour: purple throughout
Manufacture: wheel-made

Inclusion	quartz		
Frequency	rare		
Sorting	ill-sorted		
Size	<0.5mm		
Rounding			

Fabric E – Burslem Cistercian-type

Colour: Light grey (10YR 7/2) throughout
Manufacture: wheel-made

Inclusion	soft black specks	voids	
Frequency	rare	Moderate to common	
Sorting	well-sorted	ill-sorted	
Size	very fine (*c* 0.1mm)	up to 1mm	
Rounding			

Fabric F – Burslem Cistercian-type

Colour: dark grey (7.5YR N4) throughout
Manufacture: wheel-made

Inclusion	black specks	quartz	
Frequency	sparse	rare	
Sorting	ill-sorted	ill-sorted	
Size	up to 0.5mm	up to 0.5mm	
Rounding	rounded		

Fabric G – Burslem Cistercian-type

Colour: Weak red (10Y 4/2) throughout
Manufacture: wheel-made

Inclusion	linear voids	quartz	
Frequency	sparse	rare/sparse	
Sorting	ill-sorted	well-sorted	
Size	up to 10mm	up to 0.5mm	
Rounding			

Fabric H – Burslem Cistercian-type

Colour: reddish yellow (5YR 6/6) throughout
Manufacture: wheel-made

Inclusion	quartz	quartz	voids
Frequency	abundant	rare/sparse	rare/sparse
Sorting	well-sorted		ill-sorted
Size	very fine (*c* 0.1mm)	0.25mm	0.2mm
Rounding			

Fabric I – Burslem Midlands purple

Colour: red (10R 4/2) throughout
Manufacture: wheel-made

Inclusion	quartz	soft dark red specks	hard red lump
Frequency	common to abundant	sparse	rare
Sorting	well-sorted	ill-sorted	
Size	*c* 0.25mm	up to 0.1mm	2mm
Rounding	rounded	rounded	rounded

Fabric J – Burslem Midlands purple

Colour: dusky red (2.5YR 2.5/2) throughout
Manufacture: wheel-made

Inclusion	quartz	soft red specks	

Frequency	moderate	rare	
Sorting	well-sorted		
Size	*c* 0.25mm	0.1mm	
Rounding			

Fabric K – Chilvers Coton Cistercian-type

Colour: reddish yellow (5YR 6/8) throughout
Manufacture: wheel-made

Inclusion	quartz	white quartz sandstone	quartz
Frequency	abundant	rare	rare
Sorting	well-sorted	ill-sorted	?well-sorted
Size	very fine (<0.1mm)	up to 2mm	*c* 0.25
Rounding		rounded	

Fabric L – Chilvers Coton Cistercian-type

Colour: mainly dark reddish brown (2.5YR 3/4)
Manufacture: wheel-made

Inclusion	quartz	quartz	
Frequency	abundant	rare	
Sorting	well-sorted	?well-sorted	
Size	very fine (<0.1mm)	*c* 0.25	
Rounding			

Fabric M – Chilvers Coton Midlands purple

Colour: black (7.5YR N2) throughout
Manufacture: wheel-made

Inclusion	quartz	quartz sandstone	red lump
Frequency	abundant	rare	rare
Sorting	well-sorted		
Size	0.20mm	5mm	2mm
Rounding	rounded		

Fabric N – Chilvers Coton Midlands purple

Colour: brownish buff (7.5YR 6/8) throughout
Manufacture: wheel-made

Inclusion	quartz	red specks	
Frequency	abundant	moderate	
Sorting	ill-sorted	well-sorted	
Size	0.25–0.5mm	0.1mm	
Rounding	?angular		

Fabric AC – Ticknall Cistercian-type

Colour: medium red (10R 5/6) throughout
Manufacture: wheel-made

Inclusion	quartz		
Frequency	abundant		
Sorting	well-sorted		

Size	very fine (<0.1mm)		
Rounding			

Fabric AD – Ticknall Midlands purple

Colour: usually purple throughout; occasional buff (10YR 5/4) core
Manufacture: wheel-made

Inclusion	quartz		
Frequency	moderate to common		
Sorting	well-sorted		
Size	*c* 0.5mm		
Rounding	?subrounded/angular		

Fabric AE – Wednesbury Cistercian-type

Colour: purple throughout
Manufacture: wheel-made

Inclusion	quartz	quartz	
Frequency	abundant	sparse	
Sorting	well-sorted	well-sorted	
Size	fine (*c* 0.1mm)	up to 0.5mm	
Rounding		angular	

Consumer sites

Fabric P – Leicester Cistercian-type

Colour: pinkish red (7.5YR 5/6) throughout
Manufacture: wheel-made

Inclusion	quartz	cream specks	
Frequency	abundant	moderate	
Sorting	well-sorted	well-sorted	
Size	very fine (<0.1mm)	very fine (<0.1mm)	
Rounding			

Fabric R – Leicester Cistercian-type

Colour: pinkish brown (5YR 5/6) throughout
Manufacture: wheel-made

Inclusion	quartz	quartz	
Frequency	abundant	sparse	
Sorting	well-sorted	ill-sorted	
Size	fine (0.1mm)	up to *c* 0.25mm	
Rounding			

Fabric S – Leicester Midlands purple

Colour: pinkish red (5YR 5/8) throughout
Manufacture: wheel-made

Inclusion	quartz		
Frequency	moderate		
Sorting	ill-sorted		
Size	up to 1mm		
Rounding			

Fabric T – Leicester Midlands purple

Colour: buff (7.5YR 7/6) throughout
Manufacture: wheel-made

Inclusion	quartz	red pellets	
Frequency	moderate	sparse	
Sorting	ill-sorted	ill-sorted	
Size	up to 1mm	up to 1mm	
Rounding	subrounded	rounded/angular	

Fabric U – Leicester Midlands purple

Colour: reddish buff (7.5YR 6/4) throughout
Manufacture: wheel-made

Inclusion	quartz		
Frequency	abundant		
Sorting	ill-sorted		
Size	up to 1mm+		
Rounding	angular/subrounded		

Fabric V – Leicester Midlands purple

Colour: pale grey (10YR 6/1) throughout
Manufacture: wheel-made

Inclusion	quartz	glassy specks	
Frequency	abundant	sparse to moderate	
Sorting	ill-sorted	ill-sorted	
Size	up to 1mm+	up to 1mm	
Rounding	angular/subrounded		

Fabric W – Leicester Midlands purple

Colour: pale red (5YR 6/8) throughout
Manufacture: wheel-made

Inclusion	quartz		
Frequency	common		
Sorting	ill-sorted		
Size	up to 0.5mm		
Rounding	subrounded		

Fabric X – Bordesley Abbey Cistercian-type

Colour: dark red (10R 4/4) throughout
Manufacture: wheel-made

Inclusion	voids	quartz	
Frequency	sparse	rare	
Sorting	ill-sorted		
Size	<0.25mm	0.1mm	
Rounding		rounded	

Fabric Y – Bordesley Abbey Cistercian-type

Colour: medium brick red (10R 4/6) throughout
Manufacture: wheel-made

Inclusion	quartz	quartz	
Frequency	abundant	moderate	
Sorting	well-sorted	ill-sorted	
Size	very fine (<0.1mm)	up to 1mm	
Rounding			

Fabric Z – Bordesley Abbey Cistercian-type

Colour: red (5YR 6/6) throughout
Manufacture: wheel-made

Inclusion	quartz	cream specks	quartz
Frequency	abundant	abundant	rare
Sorting	well-sorted	well-sorted	
Size	very fine (<0.1mm)	fine	*c* 0.25mm
Rounding			rounded

Fabric AA – Bordesley Abbey Cistercian-type

Colour: orange (5YR 6/8) throughout

Manufacture: wheel-made

Inclusion	quartz		
Frequency	abundant		
Sorting	ill-sorted		
Size	up to 0.5mm		
Rounding			

Fabric AB – Bordesley Abbey Cistercian-type

Colour: red 2.5YR 5/6 throughout
Manufacture: wheel-made

Inclusion	quartz	black specks	
Frequency	sparse	sparse	
Sorting	ill-sorted	well-sorted	
Size	<0.5mm	<0.25mm	
Rounding			

Appendix 3

Chemical analysis – technical data

Explanation of how to read the following tables and use them in conjunction with the numbered ICPS figures.
For each Figures 2b to 7b including a number opposite each symbol, that number is the one given in the **'Case number'** column below. The original sample numbering is given in the column headed **'sample refs'**. For example, in Figure 2b, the very lowest point is numbered 79 with a black filled circle. In the sample numbering table for Figure 2b, **Case number** 79 = your sample no. 98. [The 'ICPS no REA' is the analysis number that was given to Reading]. Make sure you read from the correct column on pages which don't have column headers.

A table of sample numbers is given for every figure, because the SPSS program was run with three different data files, made up of different combinations of samples. You need to 'read off' the 'Case number' for the symbol on the Figure that you are interested in, and look up in the sample number table for that figure which of your original 'sample refs' it corresponds to. The SPSS program then will number each new data file with sequential 'Case numbers' starting at 1, 2 etc. Hence case number 55 in figure 2b may well not be the same sample as case number 55 in figure 3b. It is a tedious aspect of SPSS but we have to live with it. You may find that the case numbers are in the same sequence for more than one Figure – this is where the same **SPSS data file** was used for both figures.

Sample numbering for Figure 2b:

Case Summaries(a)

	Case Number	ICPS no REA	sample refs	Group	place	site	pot type	REGR factor score 1 for analysis 1	REGR factor score 2 for analysis 1	REGR factor score 3 for analysis 1
1	1	1	1	Wed LHS Cist	Wednesbury	Lower High Street	cist	.88017	-1.52287	.08665
2	2	2	2	Wed LHS Cist	Wednesbury	Lower High Street	cist	.19423	-1.99834	.48136
3	3	3	3	Wed LHS Cist	Wednesbury	Lower High Street	cist	.64744	-1.60281	.36145

4	4	4	4	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.23566	-1.24681	.00867
5	5	5	5	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.20368	-1.31523	-.06257
6	6	7	6	Wed TC Cist	Wednesbury	Town centre	cist	.43581	-.52452	-1.15022
7	7	8	7	Wed TC Cist	Wednesbury	Town centre	cist	-.95075	-.54620	-1.96476
8	8	9	8	Wed TC Cist	Wednesbury	Town centre	cist	.46942	-1.75112	.11424
9	9	10	9	Wed TC Cist	Wednesbury	Town centre	cist	.62569	-1.52723	-.48371
10	10	11	10	Wed TC Cist	Wednesbury	Town centre	cist	.62552	-1.37007	-.29652
11	11	12	11	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-2.49239	-.48360	-.97148
12	12	13	12	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.54268	.28392	-1.06738
13	13	14	13	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-1.88756	-.23971	-.46687

14	14	15	14	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	.56139	.86202	-2.18663
15	15	16	15	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.31503	-.04624	-1.84322
16	16	17	16	Wed MP MP	Wednesbury	Market Place	MP	1.17325	.79295	-2.24847
17	17	18	17	Wed MP MP	Wednesbury	Market Place	MP	1.40353	1.15967	-1.42911
18	18	19	18	Wed MP MP	Wednesbury	Market Place	MP	.51696	.26774	-1.28270
19	19	20	19	Wed MS MP	Wednesbury	Meeting Street	MP	-.13599	.53288	-2.10673
20	20	21	20	Wed MS MP	Wednesbury	Meeting Street	MP	.80607	-.87884	-1.19317
21	21	22	21	Burslem MP Cist	Burslem	Market Place	Cist	-.00664	1.29432	-1.08893
22	22	23	22	Burslem MP Cist	Burslem	Market Place	Cist	-.69523	.93137	-1.04093
23	23	24	23	Burslem MP Cist	Burslem	Market Place	Cist	-.36732	.76203	-1.00436
24	24	25	24	Burslem MP Cist	Burslem	Market Place	Cist	.98769	1.10823	-.60235
25	25	26	25	Burslem MP Cist	Burslem	Market Place	Cist	-1.47713	.33828	.21841
26	26	28	26	Burslem MP MP	Burslem	Market Place	MP	.04329	.84841	-.92458

27	27	29	27	Burslem MP MP	Burslem	Market Place	MP	-.15833	1.14045	-.62135
28	28	30	28	Burslem MP MP	Burslem	Market Place	MP	-.71615	.70021	-1.23692
29	29	31	29	Burslem MP MP	Burslem	Market Place	MP	-.40183	.86268	-.87566
30	30	32	30	Burslem MP MP	Burslem	Market Place	MP	1.11141	1.11924	-1.26330
31	31	33	31	Burslem Sof A Cist	Burslem	School of Art	Cist	-.41395	.66305	-1.31001
32	32	34	32	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.58918	-.32208	.61450
33	33	35	33	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.86647	.04112	.06655
34	34	36	34	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.94687	.09665	-.13221
35	35	37	35	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.09419	.00443	-.43090
36	36	38	36	Burselm S of A MP	Burslem	School of Art	MP	-1.12692	.40326	-.58771
37	37	39	37	Burselm S of A MP	Burslem	School of Art	MP	-.72050	.62549	-.42756
38	38	40	38	Burselm S of A MP	Burslem	School of Art	MP	-.88414	.37682	-.57953
39	39	41	39	Burselm S of A MP	Burslem	School of Art	MP	-1.06089	1.01484	-.40965
40	40	42	40	Burselm S of A MP	Burslem	School of Art	MP	-.62233	.59713	-.62790
41	41	43	41	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	.28317	.78487	.18090

42	42	44	42	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	.49699	1.12968	.52091
43	43	45	43	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	.53321	1.26104	.32949
44	44	46	44	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	-.09020	.49429	.18016
45	45	47	45	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	-2.05478	.12182	1.07311
46	46	49	46	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	.33781	.58818	.48892
47	47	50	47	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	.10572	.25556	1.00554
48	48	51	48	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	-.23875	.56133	.73919
49	49	52	49	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	.54509	.39707	.60864
50	50	53	50	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	-.65478	.02576	1.06283
51	51	54	51	Nuneaton Harefield MP	Nuneaton	Harefield Lane	MP	.86728	.99364	.48449
52	52	55	52	Nuneaton Harefield MP	Nuneaton	Harefield Lane	MP	1.07642	1.16653	.03605

53	53	56	53	Nuneaton Harefield MP	Nuneaton	Harefield Lane	MP	1.30348	.64221	.07220
54	54	57	54	Nuneaton Chil C MP	Nuneaton	11 Bermuda Road	MP	.94770	1.26135	-.28221
55	55	58	55	Nuneaton Chil C Scott MP	Nuneaton	16–22 Bermuda Road	MP	-.63324	.35768	1.41341
56	56	59	75	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.33689	-1.33476	.05208
57	57	60	76	Leicester A Friars Cist	Leicester	Austin Friars	Cist	-.61394	-.66190	1.42193
58	58	61	77	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.04071	-1.71041	.19169
59	59	62	78	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.09569	.00496	.80334
60	60	63	79	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.98373	.07054	.55701
61	61	64	80	Leicester A Friars MP	Leicester	Austin Friars	MP	-.31039	-.06487	2.09071
62	62	65	81	Leicester A Friars MP	Leicester	Austin Friars	MP	.31782	.54484	1.45538
63	63	66	82	Leicester A Friars MP	Leicester	Austin Friars	MP	.88604	.82630	1.23061

64	64	67	83	Leicester A Friars MP	Leicester	Austin Friars	MP	.82602	.69944	1.32982
65	65	68	84	Leicester A Friars MP	Leicester	Austin Friars	MP	.24209	1.24231	1.56787
66	66	69	85	Leicester A Friars2 MP	Leicester	Austin Friars	MP	.91283	1.33784	.69763
67	67	71	86	Leicester A Friars2 MP	Leicester	Austin Friars	MP	.55159	1.50968	1.22032
68	68	72	87	Leicester A Friars2 MP	Leicester	Austin Friars	MP	.46660	.93153	1.29860
69	69	73	88	Leicester A Friars2 MP	Leicester	Austin Friars	MP	.99021	1.32222	.91116
70	70	74	89	Leicester A Friars2 MP	Leicester	Austin Friars	MP	1.31735	1.31278	1.00830
71	71	75	90	Leicester A Friars3 MP	Leicester	Austin Friars	MP	-.69491	.87747	1.71770
72	72	76	91	Leicester A Friars3 MP	Leicester	Austin Friars	MP	-1.59838	.37271	2.21049
73	73	77	92	Leicester A Friars3 MP	Leicester	Austin Friars	MP	-.93831	.63930	2.05693
74	74	78	93	Leicester A Friars4 MP	Leicester	Austin Friars	MP	.19744	-.51684	1.29011

75	75	79	94	Bordesley gp24		Bordesley Abbey	Cist	.18837	-.69172	-.92060
76	76	80	95	Bordesley gp 25		Bordesley Abbey	Cist	-1.52356	-1.17885	.26316
77	77	81	96	Bordesley gp 25		Bordesley Abbey	Cist	-.61586	-.90565	-.47296
78	78	82	97	Bordesley gp 26		Bordesley Abbey	Cist	1.55872	-1.31713	.03029
79	79	83	98	Bordesley gp 26		Bordesley Abbey	Cist	-.44623	-2.03811	.71821
80	80	84	99	Bordesley gp 26		Bordesley Abbey	Cist	.16583	-1.68530	.47970
81	81	85	100	Bordesley gp 26		Bordesley Abbey	Cist	1.13842	-1.58499	.04076
82	82	86	101	Bordesley gp 26		Bordesley Abbey	Cist	1.10664	-.77653	.62626
83	83	87	102	Bordesley gp 27		Bordesley Abbey	Cist	1.12616	-1.14321	.10361
84	84	88	103	Bordesley gp 27		Bordesley Abbey	Cist	.92692	-1.56924	.14912
85	85	89	104	Bordesley gp 28		Bordesley Abbey	Cist	-1.24337	-.98708	.03546
86	86	90	105	Bordesley gp 28		Bordesley Abbey	Cist	-1.34546	-1.72765	-.21157
87	87	92	106	Bordesley gp 28		Bordesley Abbey	Cist	-.42757	-.52636	-.53844
88	88	93	107	Bordesley gp 28		Bordesley Abbey	Cist	-.00677	-.83153	-1.00980
89	89	94	108	Bordesley gp 28		Bordesley Abbey	Cist	1.12915	-1.59613	-.03352
90	90	95	109	Bordesley gp 28		Bordesley Abbey	Cist	-.01432	-.33616	-.31943
Total N		90	90	90	90	90	90	90	90	90

a Limited to first 300 cases.

Sample numbering for Figure 3b:

Case Summaries(a)

	Case Number	ICPS no REA	sample refs	Group	place	site	pot type	REGR factor score 1 for analysis 2	REGR factor score 2 for analysis 2	REGR factor score 3 for analysis 2
1	1	1	1	Wed LHS Cist	Wednesbury	Lower High Street	cist	.90702	-1.33880	-.22934
2	2	2	2	Wed LHS Cist	Wednesbury	Lower High Street	cist	.25381	-1.87907	.15416
3	3	3	3	Wed LHS Cist	Wednesbury	Lower High Street	cist	.69022	-1.42412	.17235
4	4	4	4	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.24520	-.98733	-.15689
5	5	5	5	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.21024	-1.05348	-.33337
6	6	7	6	Wed TC Cist	Wednesbury	Town centre	cist	.45018	-.20326	-1.35937
7	7	8	7	Wed TC Cist	Wednesbury	Town centre	cist	-.91155	-.26042	-2.20061
8	8	9	8	Wed TC Cist	Wednesbury	Town centre	cist	.50844	-1.58652	-.27434

9	9	10	9	Wed TC Cist	Wednesbury	Town centre	cist	.65195	-1.24685	-.81360
10	10	11	10	Wed TC Cist	Wednesbury	Town centre	cist	.66054	-1.09104	-.52464
11	11	12	11	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-2.37429	-.46489	-1.38673
12	12	13	12	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.48385	.40840	-1.10991
13	13	14	13	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-1.76711	-.17584	-.13669
14	14	15	14	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	.55182	1.34689	-1.82703
15	15	16	15	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.28726	.40422	-1.80577
16	16	17	16	Wed MP MP	Wednesbury	Market Place	MP	1.11064	1.33493	-1.88440
17	17	18	17	Wed MP MP	Wednesbury	Market Place	MP	1.36670	1.68768	-.60593

18	18	19	18	Wed MP MP	Wednesbury	Market Place	MP	.50776	.61849	-1.07546
19	19	20	19	Wed MS MP	Wednesbury	Meeting Street	MP	-.12312	.94520	-1.92770
20	20	21	20	Wed MS MP	Wednesbury	Meeting Street	MP	.78458	-.47065	-1.29403
21	21	22	21	Burslem MP Cist	Burslem	Market Place	Cist	-.04330	1.40874	-.88898
22	22	23	22	Burslem MP Cist	Burslem	Market Place	Cist	-.65214	1.10196	-.60119
23	23	24	23	Burslem MP Cist	Burslem	Market Place	Cist	-.34703	.95457	-.62282
24	24	25	24	Burslem MP Cist	Burslem	Market Place	Cist	.97032	1.30723	.07794
25	25	26	25	Burslem MP Cist	Burslem	Market Place	Cist	-1.42642	.19943	.44142
26	26	28	26	Burslem MP MP	Burslem	Market Place	MP	.07172	1.09083	-.40251
27	27	29	27	Burslem MP MP	Burslem	Market Place	MP	-.13615	1.31320	.10098
28	28	30	28	Burslem MP MP	Burslem	Market Place	MP	-.68102	.95011	-.88144
29	29	31	29	Burslem MP MP	Burslem	Market Place	MP	-.37288	1.06603	-.43683
30	30	32	30	Burslem MP MP	Burslem	Market Place	MP	1.07704	1.47694	-.62374
31	31	33	31	Burslem Sof A Cist	Burslem	School of Art	Cist	-.43970	.89989	-1.03106
32	32	34	32	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.46504	-.54538	.91285
33	33	35	33	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.79682	-.08500	.27707

34	34	36	34	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.88140	.04281	.15669
35	35	37	35	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.01743	.00066	-.13792
36	36	38	36	Burselm S of A MP	Burslem	School of Art	MP	-1.06546	.58077	-.04265
37	37	39	37	Burselm S of A MP	Burslem	School of Art	MP	-.67872	.76431	.13976
38	38	40	38	Burselm S of A MP	Burslem	School of Art	MP	-.84885	.55308	-.03843
39	39	41	39	Burselm S of A MP	Burslem	School of Art	MP	-.99046	1.09938	.30927
40	40	42	40	Burselm S of A MP	Burslem	School of Art	MP	-.59561	.70064	-.21986
41	56	59	75	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.34791	-1.05833	-.14173
42	57	60	76	Leicester A Friars Cist	Leicester	Austin Friars	Cist	-.46603	-.88881	1.74842
43	58	61	77	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.10670	-1.53823	-.03651
44	59	62	78	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.16244	.02248	1.42060
45	60	63	79	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.03851	.08359	.99500
46	75	79	94	Bordesley gp24		Bordesley Abbey	Cist	.21625	-.34707	-.78656

47	76	80	95	Bordesley gp 25		Bordesley Abbey	Cist	-1.42004	-1.17239	.21042
48	77	81	96	Bordesley gp 25		Bordesley Abbey	Cist	-.54853	-.68362	-.42810
49	78	82	97	Bordesley gp 26		Bordesley Abbey	Cist	1.55229	-1.01245	-.22173
50	79	83	98	Bordesley gp 26		Bordesley Abbey	Cist	-.35326	-2.02703	.39630
51	80	84	99	Bordesley gp 26		Bordesley Abbey	Cist	.21307	-1.57913	.25642
52	81	85	100	Bordesley gp 26		Bordesley Abbey	Cist	1.15505	-1.31815	-.19717
53	82	86	101	Bordesley gp 26		Bordesley Abbey	Cist	1.15069	-.74301	.74669
54	83	87	102	Bordesley gp 27		Bordesley Abbey	Cist	1.15584	-.88382	.10239
55	84	88	103	Bordesley gp 27		Bordesley Abbey	Cist	.95572	-1.36383	-.10807
56	85	89	104	Bordesley gp 28		Bordesley Abbey	Cist	-1.13599	-.93614	.02149
57	86	90	105	Bordesley gp 28		Bordesley Abbey	Cist	-1.24392	-1.61260	-.46738
58	87	92	106	Bordesley gp 28		Bordesley Abbey	Cist	-.39179	-.39841	-.59714
59	88	93	107	Bordesley gp 28		Bordesley Abbey	Cist	.02196	-.49392	-.99926
60	89	94	108	Bordesley gp 28		Bordesley Abbey	Cist	1.14528	-1.31915	-.25994
61	90	95	109	Bordesley gp 28		Bordesley Abbey	Cist	.02746	-.18770	-.13638
Total N		61	61	61	61	61	61	61	61	61

a Limited to first 300 cases.

Sample numbering for Figure 4b:

Case Summaries(a)

	Case Number	ICPS no REA	sample refs	Group	place	site	pot type	REGR factor score 1 for analysis 2	REGR factor score 2 for analysis 2	REGR factor score 3 for analysis 2
1	11	12	11	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-1.85082	-2.50654	-.57113
2	12	13	12	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	.11080	-1.36503	.76385
3	13	14	13	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-1.22308	-1.17808	1.66226
4	14	15	14	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	1.09291	-1.11075	.35376

5	15	16	15	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	.22372	-2.42332	-.10631
6	16	17	16	Wed MP MP	Wednesbury	Market Place	MP	1.43054	-.65487	-2.26950
7	17	18	17	Wed MP MP	Wednesbury	Market Place	MP	2.08354	1.03054	.43899
8	18	19	18	Wed MP MP	Wednesbury	Market Place	MP	.96308	-.54161	-.07974
9	19	20	19	Wed MS MP	Wednesbury	Meeting Street	MP	.43081	-1.15642	-.59207
10	21	22	21	Burslem MP Cist	Burslem	Market Place	Cist	.32277	.56073	-1.62041
11	22	23	22	Burslem MP Cist	Burslem	Market Place	Cist	-.03602	.30111	.65033
12	23	24	23	Burslem MP Cist	Burslem	Market Place	Cist	.16156	.05564	-.11053
13	24	25	24	Burslem MP Cist	Burslem	Market Place	Cist	1.34554	.55306	.31280
14	25	26	25	Burslem MP Cist	Burslem	Market Place	Cist	-.83455	.97859	-.31430
15	26	28	26	Burslem MP MP	Burslem	Market Place	MP	.60674	.07335	1.33812
16	27	29	27	Burslem MP MP	Burslem	Market Place	MP	.52434	.97079	1.32272
17	28	30	28	Burslem MP MP	Burslem	Market Place	MP	-.12916	-.04438	-.22397
18	29	31	29	Burslem MP MP	Burslem	Market Place	MP	.23450	-.03360	1.45941
19	30	32	30	Burslem MP MP	Burslem	Market Place	MP	1.48603	.35077	-.53074

20	31	33	31	Burslem Sof A Cist	Burslem	School of Art	Cist	-.04384	.61602	-2.44330
21	32	34	32	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.77834	1.20739	-.22811
22	33	35	33	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.28341	.85468	-.79451
23	34	36	34	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.26244	1.05145	-.58137
24	35	37	35	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.41314	.38074	-.19620
25	36	38	36	Burslem S of A MP	Burslem	School of Art	MP	-.43103	.13557	.39517
26	37	39	37	Burslem S of A MP	Burslem	School of Art	MP	-.02541	.60824	.52393
27	38	40	38	Burslem S of A MP	Burslem	School of Art	MP	-.28065	.35046	.38016
28	39	41	39	Burslem S of A MP	Burslem	School of Art	MP	-.24153	1.07011	1.25973
29	40	42	40	Burslem S of A MP	Burslem	School of Art	MP	-.18346	-.13467	-.19903
Total N		29	29	29	29	29	29	29	29	29

a Limited to first 300 cases.

Sample numbering for Figure 5b:

Case Summaries(a)

	Case Number	ICPS no REA	sample refs	Group	place	site	pot type	REGR factor score 1 for analysis 2	REGR factor score 2 for analysis 2	REGR factor score 3 for analysis 2

1	1	1	1	Wed LHS Cist	Wednesbury	Lower High Street	cist	.56389	-1.73952	-.13377
2	2	2	2	Wed LHS Cist	Wednesbury	Lower High Street	cist	.02983	-2.09414	.41324
3	3	3	3	Wed LHS Cist	Wednesbury	Lower High Street	cist	.48890	-1.72700	.23301
4	4	4	4	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.06476	-1.35334	-.27163
5	5	5	5	Wed LHS Cist	Wednesbury	Lower High Street	cist	.91504	-1.48259	-.49691
6	6	7	6	Wed TC Cist	Wednesbury	Town centre	cist	.28133	-.28287	-1.63836
7	7	8	7	Wed TC Cist	Wednesbury	Town centre	cist	-1.08096	-.19437	-2.22012
8	8	9	8	Wed TC Cist	Wednesbury	Town centre	cist	.25439	-1.75457	-.25469
9	9	10	9	Wed TC Cist	Wednesbury	Town centre	cist	.44205	-1.30426	-.93366
10	10	11	10	Wed TC Cist	Wednesbury	Town centre	cist	.56039	-1.42363	-.41468
11	11	12	11	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-2.58261	-.19316	-1.54077

12	12	13	12	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.59281	.37059	-1.52963
13	13	14	13	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-1.90959	-.05315	-.09351
14	14	15	14	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	.44070	.97192	-2.40004
15	15	16	15	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.50111	.21622	-2.28593
16	16	17	16	Wed MP MP	Wednesbury	Market Place	MP	.96560	1.32406	-2.28390
17	17	18	17	Wed MP MP	Wednesbury	Market Place	MP	1.22900	1.21906	-1.18666
18	18	19	18	Wed MP MP	Wednesbury	Market Place	MP	.38194	.34217	-1.40242
19	19	20	19	Wed MS MP	Wednesbury	Meeting Street	MP	-.22184	.85764	-2.36120
20	20	21	20	Wed MS MP	Wednesbury	Meeting Street	MP	.59182	-.59005	-1.48322
21	21	22	21	Burslem MP Cist	Burslem	Market Place	Cist	-.22832	1.43778	-1.17080
22	22	23	22	Burslem MP Cist	Burslem	Market Place	Cist	-.72599	1.05614	-.69940

23	23	24	23	Burslem MP Cist	Burslem	Market Place	Cist	-.50361	.90670	-.82494
24	24	25	24	Burslem MP Cist	Burslem	Market Place	Cist	.76097	1.31861	-.30535
25	25	26	25	Burslem MP Cist	Burslem	Market Place	Cist	-1.65469	.43072	.39367
26	26	28	26	Burslem MP MP	Burslem	Market Place	MP	.00071	.91586	-.44410
27	27	29	27	Burslem MP MP	Burslem	Market Place	MP	-.21415	1.21477	-.00044
28	28	30	28	Burslem MP MP	Burslem	Market Place	MP	-.77092	.90931	-.91950
29	29	31	29	Burslem MP MP	Burslem	Market Place	MP	-.39078	.91667	-.39262
30	30	32	30	Burslem MP MP	Burslem	Market Place	MP	.86616	1.38512	-1.14865
31	31	33	31	Burslem Sof A Cist	Burslem	School of Art	Cist	-.59348	1.15464	-1.05260
32	32	34	32	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.94331	-.36185	1.19381
33	33	35	33	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.02246	.34557	.38666
34	34	36	34	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.08884	.34953	.41146
35	35	37	35	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.19861	.32699	.00429
36	36	38	36	Burslem S of A MP	Burslem	School of Art	MP	-1.27825	.65483	-.20884
37	37	39	37	Burslem S of A MP	Burslem	School of Art	MP	-.90073	.80025	-.13084
38	38	40	38	Burslem S of A MP	Burslem	School of Art	MP	-1.05117	.58309	-.14307

39	39	41	39	Burslem S of A MP	Burslem	School of Art	MP	-1.14388	1.15038	.08473
40	40	42	40	Burslem S of A MP	Burslem	School of Art	MP	-.82695	.89036	-.37005
41	41	43	41	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	.02077	.89512	1.00890
42	42	44	42	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	.19834	1.23124	1.47093
43	43	45	43	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	.30719	1.34651	1.33981
44	44	46	44	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	-.33197	.67367	.94409
45	45	47	45	Nuneaton Chil C May Cist	Nuneaton	Chilvers Coton (Mayes)	Cist	-2.25371	.21758	1.89618
46	46	49	46	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	.14027	.68246	1.33584
47	47	50	47	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	-.07053	.07676	1.93944
48	48	51	48	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	-.41613	.59362	1.88381
49	49	52	49	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	.26132	.40453	1.16007

50	50	53	50	Nuneaton Chil C May MP	Nuneaton	Chilvers Coton (Mayes)	MP	-.79553	-.06964	2.00684
51	51	54	51	Nuneaton Harefield MP	Nuneaton	Harefield Lane	MP	.61024	.79479	.53789
52	52	55	52	Nuneaton Harefield MP	Nuneaton	Harefield Lane	MP	.80493	1.02899	.22198
53	53	56	53	Nuneaton Harefield MP	Nuneaton	Harefield Lane	MP	.99470	.54393	.01951
54	54	57	54	Nuneaton Chil C MP	Nuneaton	11 Bermuda Road (NB99)	MP	.75619	.88085	.22907
55	55	58	55	Nuneaton Chil C Scott MP	Nuneaton	16–22 Bermuda Road (NCC79)	MP	-.82652	.02911	1.86915
56	56	59	75	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.11794	-1.48957	-.33585
57	57	60	76	Leicester A Friars Cist	Leicester	Austin Friars	Cist	-.94843	-.80885	1.55890
58	58	61	77	Leicester A Friars Cist	Leicester	Austin Friars	Cist	-.04244	-1.88268	.26744
59	59	62	78	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.75381	-.12900	.96515
60	60	63	79	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.65454	.10421	.66913

61	75	79	94	Bordesley gp24		Bordesley Abbey	Cist	.06363	-.48772	-.94998
62	76	80	95	Bordesley gp 25		Bordesley Abbey	Cist	-1.65529	-1.18247	.44256
63	77	81	96	Bordesley gp 25		Bordesley Abbey	Cist	-.77611	-.76720	-.58693
64	78	82	97	Bordesley gp 26		Bordesley Abbey	Cist	1.23014	-1.58399	-.46433
65	79	83	98	Bordesley gp 26		Bordesley Abbey	Cist	-.61159	-2.07045	.53949
66	80	84	99	Bordesley gp 26		Bordesley Abbey	Cist	.00773	-1.85776	.53583
67	81	85	100	Bordesley gp 26		Bordesley Abbey	Cist	.93421	-1.59897	-.33648
68	82	86	101	Bordesley gp 26		Bordesley Abbey	Cist	.80801	-.51077	.66811
69	83	87	102	Bordesley gp 27		Bordesley Abbey	Cist	.88774	-1.12151	-.22075
70	84	88	103	Bordesley gp 27		Bordesley Abbey	Cist	.71584	-1.62857	-.20351
71	85	89	104	Bordesley gp 28		Bordesley Abbey	Cist	-1.41341	-1.05230	.09778
72	86	90	105	Bordesley gp 28		Bordesley Abbey	Cist	-1.45978	-1.55800	-.24936
73	87	92	106	Bordesley gp 28		Bordesley Abbey	Cist	-.63515	-.20932	-.76384
74	88	93	107	Bordesley gp 28		Bordesley Abbey	Cist	-.11003	-.52333	-1.19136
75	89	94	108	Bordesley gp 28		Bordesley Abbey	Cist	.90689	-1.57208	-.41578
76	90	95	109	Bordesley gp 28		Bordesley Abbey	Cist	-.24285	-.13148	-.39964

77		91	V4266	61	Ticknall Peat's MP	V4266	Ticknall site 6 Peat's Close	MP	1.61703	1.32618	.77400
78		92	V4267	62	Ticknall Peat's MP	V4267	Ticknall site 6 Peat's Close	MP	1.01610	.54294	1.05807
79		93	V4268	63	Ticknall Peat's MP	V4268	Ticknall site 6 Peat's Close	MP	1.90880	1.20458	.70613
80		94	V4269	64	Ticknall Peat's MP	V4269	Ticknall site 6 Peat's Close	MP	.98599	.44432	.53524
81		95	V4270	56	Ticknall Peat's Cist	V4270	Ticknall site 6 Peat's Close	Cist	.58677	-.27028	.66262
82		96	V4271	57	Ticknall Peat's Cist	V4271	Ticknall site 6 Peat's Close	Cist	.96668	-.75655	.00868
83		97	V4272	58	Ticknall Peat's Cist	V4272	Ticknall site 6 Peat's Close	Cist	.11568	-.39712	.58643
84		98	V4273	59	Ticknall Peat's Cist	V4273	Ticknall site 6 Peat's Close	Cist	.68685	-1.01926	.33417

85	99	V4274	60	Ticknall Peat's Cist	V4274	Ticknall site 6 Peat's Close	Cist	.42393	-.81466	.51732
86	100	V4275	65	Ticknall Church La Cist	V4275	Ticknall site 2 Church La	Cist	.27841	-.97560	.40368
87	101	V4276	66	Ticknall Church La Cist	V4276	Ticknall site 2 Church La	Cist	1.11794	.66666	.98081
88	102	V4277	67	Ticknall Church La Cist	V4277	Ticknall site 2 Church La	Cist	.90648	.95205	.67510
89	103	V4278	68	Ticknall Church La Cist	V4278	Ticknall site 2 Church La	Cist	1.41079	.87735	.82324
90	104	V4279	69	Ticknall Church La Cist	V4279	Ticknall site 2 Church La	Cist	1.04194	.65671	.98099
91	105	V4280	70	Ticknall Church La MP	V4280	Ticknall site 2 Church La	MP	.63009	.92827	.60505
92	106	V4281	71	Ticknall Church La MP	V4281	Ticknall site 2 Church La	MP	.37240	.43920	.65705

93	107	V4282	72	Ticknall Church La MP	V4282	Ticknall site 2 Church La	MP	1.06031	-.36104	.06998
94	108	V4283	73	Ticknall Church La MP	V4283	Ticknall site 2 Church La	MP	.46398	.31400	.87323
95	109	V4284	74	Ticknall Church La MP	V4284	Ticknall site 2 Church La	MP	.95985	.86954	.70176
96	110	K118.76		Sneyd Green	K118.76	Sneyd Green	Roof	-.47567	-.41664	-.67722
97	111	K118.11		Sneyd Green	K118.11	Sneyd Green	Pot	.50943	.67451	-.35358
98	112	C.S.8		Sneyd Green	C.S.8	Sneyd Green	Pot	.41883	.35262	-.79136
Total N		98	98	98	98	98	98	98	98	98

a Limited to first 300 cases.

Sample numbering for Figure 6b:

Case Summaries(a)

	Case Number	ICPS no REA	sample refs	Group	place	site	pot type	REGR factor score 1 for analysis 3	REGR factor score 2 for analysis 3	REGR factor score 3 for analysis 3
1	1	1	1	Wed LHS Cist	Wednesbury	Lower High Street	cist	.91026	-1.18133	-.27281

2	2	2	2	Wed LHS Cist	Wednesbury	Lower High Street	cist	.38088	-1.65553	.60389
3	3	3	3	Wed LHS Cist	Wednesbury	Lower High Street	cist	.77854	-1.18132	.60615
4	4	4	4	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.30973	-.59404	-.05000
5	5	5	5	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.18645	-.72523	-.21251
6	6	7	6	Wed TC Cist	Wednesbury	Town centre	cist	.48385	.29561	-.94425
7	7	8	7	Wed TC Cist	Wednesbury	Town centre	cist	-.79775	.01535	-2.26019
8	8	9	8	Wed TC Cist	Wednesbury	Town centre	cist	.57652	-1.26009	-.12452
9	9	10	9	Wed TC Cist	Wednesbury	Town centre	cist	.71888	-.67370	-.65908
10	10	11	10	Wed TC Cist	Wednesbury	Town centre	cist	.83812	-.80233	-.34057
11	11	12	11	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-2.31368	-.48132	-.29711
12	12	13	12	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.41664	.54963	-.32387

13	13	14	13	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-1.69623	-.45757	-.06053
14	14	15	14	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	.53459	1.55071	-1.66233
15	15	16	15	Wed LHS MP	Wednesbury	Lower High Street service trenches	MP	-.33661	.61672	-1.25113
16	16	17	16	Wed MP MP	Wednesbury	Market Place	MP	.99482	2.04255	-1.19306
17	17	18	17	Wed MP MP	Wednesbury	Market Place	MP	1.21908	1.96549	-.37447
18	18	19	18	Wed MP MP	Wednesbury	Market Place	MP	.51406	.89102	-1.16310
19	19	20	19	Wed MS MP	Wednesbury	Meeting Street	MP	-.11860	1.30727	-1.33076
20	20	21	20	Wed MS MP	Wednesbury	Meeting Street	MP	.77776	-.03006	-2.38366
21	21	22	21	Burslem MP Cist	Burslem	Market Place	Cist	-.19796	1.75438	.58340
22	22	23	22	Burslem MP Cist	Burslem	Market Place	Cist	-.65282	1.17346	.60962
23	23	24	23	Burslem MP Cist	Burslem	Market Place	Cist	-.43489	1.08811	.27722
24	24	25	24	Burslem MP Cist	Burslem	Market Place	Cist	.81211	1.58326	.62522

25	25	26	25	Burslem MP Cist	Burslem	Market Place	Cist	-1.53790	.18696	1.62971
26	26	28	26	Burslem MP MP	Burslem	Market Place	MP	.08768	1.14058	.50677
27	27	29	27	Burslem MP MP	Burslem	Market Place	MP	-.18294	1.26306	.84437
28	28	30	28	Burslem MP MP	Burslem	Market Place	MP	-.68754	1.06690	.06594
29	29	31	29	Burslem MP MP	Burslem	Market Place	MP	-.30310	.99845	.31239
30	30	32	30	Burslem MP MP	Burslem	Market Place	MP	.90293	1.85458	-.39695
31	31	33	31	Burslem Sof A Cist	Burslem	School of Art	Cist	-.56273	1.40826	.05586
32	32	34	32	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.70015	-.98043	.75118
33	33	35	33	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.88700	.01829	1.08542
34	34	36	34	Burslem Sof A Cist	Burslem	School of Art	Cist	-1.93985	.00624	.60356
35	35	37	35	Burslem Sof A Cist	Burslem	School of Art	Cist	-2.04122	-.00088	.04161
36	36	38	36	Burslem S of A MP	Burslem	School of Art	MP	-1.15524	.50514	.11035
37	37	39	37	Burslem S of A MP	Burslem	School of Art	MP	-.79939	.73267	.27868
38	38	40	38	Burslem S of A MP	Burslem	School of Art	MP	-.93194	.49870	-.22093
39	39	41	39	Burslem S of A MP	Burslem	School of Art	MP	-1.06968	.92555	.58383

40	40	42	40	Burslem S of A MP	Burslem	School of Art	MP	-.71625	.74950	.03015
41	56	59	75	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.38266	-.70617	-.03820
42	57	60	76	Leicester A Friars Cist	Leicester	Austin Friars	Cist	-.63558	-1.16158	1.94763
43	58	61	77	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.28189	-1.50741	.26516
44	59	62	78	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.93598	.07374	1.62683
45	60	63	79	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.80332	.29385	1.99470
46	75	79	94	Bordesley gp24		Bordesley Abbey	Cist	.26531	-.11740	-1.60611
47	76	80	95	Bordesley gp 25		Bordesley Abbey	Cist	-1.35899	-1.52058	-.98404
48	77	81	96	Bordesley gp 25		Bordesley Abbey	Cist	-.51657	-.76758	-1.81518
49	78	82	97	Bordesley gp 26		Bordesley Abbey	Cist	1.48815	-.69630	-.11473
50	79	83	98	Bordesley gp 26		Bordesley Abbey	Cist	-.23490	-1.93398	-.29619
51	80	84	99	Bordesley gp 26		Bordesley Abbey	Cist	.34393	-1.59700	-.33598
52	81	85	100	Bordesley gp 26		Bordesley Abbey	Cist	1.19752	-.83920	-.00373
53	82	86	101	Bordesley gp 26		Bordesley Abbey	Cist	1.04881	-.37405	1.17521

54	83	87	102	Bordesley gp 27		Bordesley Abbey	Cist	1.12617	-.49771	.18156
55	84	88	103	Bordesley gp 27		Bordesley Abbey	Cist	1.01082	-.97924	.02021
56	85	89	104	Bordesley gp 28		Bordesley Abbey	Cist	-1.10954	-1.21701	-.46220
57	86	90	105	Bordesley gp 28		Bordesley Abbey	Cist	-1.10084	-1.67343	-1.16828
58	87	92	106	Bordesley gp 28		Bordesley Abbey	Cist	-.41766	-.19358	-1.40748
59	88	93	107	Bordesley gp 28		Bordesley Abbey	Cist	.10359	-.15625	-2.06331
60	89	94	108	Bordesley gp 28		Bordesley Abbey	Cist	1.17769	-.84447	-.24594
61	90	95	109	Bordesley gp 28		Bordesley Abbey	Cist	-.04448	-.03219	-.70699
62	95	V4270	56	Ticknall Peat's Cist	V4270	Ticknall site 6 Peat's Close	Cist	.71260	.06293	1.60942
63	96	V4271	57	Ticknall Peat's Cist	V4271	Ticknall site 6 Peat's Close	Cist	1.10575	-.06636	.49303
64	97	V4272	58	Ticknall Peat's Cist	V4272	Ticknall site 6 Peat's Close	Cist	.26180	-.16391	1.52794
65	98	V4273	59	Ticknall Peat's Cist	V4273	Ticknall site 6 Peat's Close	Cist	.85030	-.46989	1.02957

66	99	V4274	60	Ticknall Peat's Cist	V4274	Ticknall site 6 Peat's Close	Cist	.55759	-.34637	1.47574
67	100	V4275	65	Ticknall Church La Cist	V4275	Ticknall site 2 Church La	Cist	.44253	-.55475	1.19865
68	110	K118.76		Sneyd Green	K118.76	Sneyd Green	Roof	-.29159	-.15958	.10549
69	111	K118.11		Sneyd Green	K118.11	Sneyd Green	Pot	.56673	1.06708	1.00624
70	112	C.S.8		Sneyd Green	C.S.8	Sneyd Green	Pot	.50086	.91379	.90753
Total N		70	70	70	70	70	70	70	70	70

a Limited to first 300 cases.

Sample numbering for Figure 7b:

Case Summaries(a)

	Case Number	ICPS no REA	sample refs	Group	place	site	pot type	REGR factor score 1 for analysis 4	REGR factor score 2 for analysis 4	REGR factor score 3 for analysis 4
1	1	1	1	Wed LHS Cist	Wednesbury	Lower High Street	cist	.51471	1.10565	.22671
2	2	2	2	Wed LHS Cist	Wednesbury	Lower High Street	cist	-.13507	1.42340	-.98008

3	3	3	3	Wed LHS Cist	Wednesbury	Lower High Street	cist	.40619	1.03817	-.59750
4	4	4	4	Wed LHS Cist	Wednesbury	Lower High Street	cist	1.08797	.74307	.60243
5	5	5	5	Wed LHS Cist	Wednesbury	Lower High Street	cist	.90923	.84405	.54482
6	6	7	6	Wed TC Cist	Wednesbury	Town centre	cist	.12509	-.56315	1.69397
7	7	8	7	Wed TC Cist	Wednesbury	Town centre	cist	-1.60187	-1.15292	1.84881
8	8	9	8	Wed TC Cist	Wednesbury	Town centre	cist	.09668	1.04153	-.15535
9	9	10	9	Wed TC Cist	Wednesbury	Town centre	cist	.27881	.50385	.57314
10	10	11	10	Wed TC Cist	Wednesbury	Town centre	cist	.42871	.81959	.36083
11	56	59	75	Leicester A Friars Cist	Leicester	Austin Friars	Cist	1.19838	.76890	.35657
12	57	60	76	Leicester A Friars Cist	Leicester	Austin Friars	Cist	-1.21337	-.28229	-2.03378
13	58	61	77	Leicester A Friars Cist	Leicester	Austin Friars	Cist	-.30133	1.23709	-.81413
14	59	62	78	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.88184	-.85838	-.45509

15	60	63	79	Leicester A Friars Cist	Leicester	Austin Friars	Cist	.80657	-1.65986	-.81440
16	75	79	94	Bordesley gp24		Bordesley Abbey	Cist	-.33283	-.26364	1.41609
17	76	80	95	Bordesley gp 25		Bordesley Abbey	Cist	-2.51053	.05412	-.57499
18	77	81	96	Bordesley gp 25		Bordesley Abbey	Cist	-1.43251	.05655	.79929
19	78	82	97	Bordesley gp 26		Bordesley Abbey	Cist	1.31576	.92496	.48037
20	79	83	98	Bordesley gp 26		Bordesley Abbey	Cist	-1.05098	1.58039	-.73116
21	80	84	99	Bordesley gp 26		Bordesley Abbey	Cist	-.27252	1.41397	-.27270
22	81	85	100	Bordesley gp 26		Bordesley Abbey	Cist	.92616	.84380	.12121
23	82	86	101	Bordesley gp 26		Bordesley Abbey	Cist	.87981	-.61426	-.73037
24	83	87	102	Bordesley gp 27		Bordesley Abbey	Cist	.87337	.55394	.21462
25	84	88	103	Bordesley gp 27		Bordesley Abbey	Cist	.68683	.98962	.08260
26	85	89	104	Bordesley gp 28		Bordesley Abbey	Cist	-2.10119	.13748	-.42849
27	86	90	105	Bordesley gp 28		Bordesley Abbey	Cist	-2.21781	.66891	-.49869
28	87	92	106	Bordesley gp 28		Bordesley Abbey	Cist	-1.12124	-.44355	1.43845
29	88	93	107	Bordesley gp 28		Bordesley Abbey	Cist	-.54234	-.18830	1.66506
30	89	94	108	Bordesley gp 28		Bordesley Abbey	Cist	.87461	.87686	.24426

31	90	95	109	Bordesley gp 28		Bordesley Abbey	Cist	-.57821	-.63923	.99218
32	95	V4270	56	Ticknall Peat's Cist	V4270	Ticknall site 6 Peat's Close	Cist	.56690	-1.49531	-1.16004
33	96	V4271	57	Ticknall Peat's Cist	V4271	Ticknall site 6 Peat's Close	Cist	.93673	-.81504	-.34378
34	97	V4272	58	Ticknall Peat's Cist	V4272	Ticknall site 6 Peat's Close	Cist	.02906	-1.50588	-1.49031
35	98	V4273	59	Ticknall Peat's Cist	V4273	Ticknall site 6 Peat's Close	Cist	.63558	-.70079	-1.11093
36	99	V4274	60	Ticknall Peat's Cist	V4274	Ticknall site 6 Peat's Close	Cist	.31370	-1.24496	-1.63056
37	100	V4275	65	Ticknall Church La Cist	V4275	Ticknall site 2 Church La	Cist	.12669	-1.04734	-1.62315
38	110	K118.76		Sneyd Green	K118.76	Sneyd Green	Roof	-.73341	-.93685	.16444
39	111	K118.11		Sneyd Green	K118.11	Sneyd Green	Pot	.66302	-1.73062	1.30378
40	112	C.S.8		Sneyd Green	C.S.8	Sneyd Green	Pot	.58282	-1.48352	1.31586
Total N		40	40	40	40	40	40	40	40	40

a Limited to first 300 cases.

Appendix 4

Technical report on the petrography of Cistercian-type and Midlands purple wares from the West Midlands

R A Ixer
Completed 31 August 2010

General introduction

Fabric descriptions of pottery with a hand lens have the great advantages of ease and speed plus significant data can be obtained, notably firing colour, grain size, the relative abundances of non-plastics and their distribution together with an idea of the type of clasts/'temper'. Accurate provenancing of raw materials used in the manufacture of ceramics is rarely possible macroscopically.

Despite the additional time and cost and damage to the sample there is little that can substitute for a comprehensive petrographical description using a thin section or polished thin section, investigated firstly with a x20 hand lens followed by the use of the petrological microscope at successively higher magnifications. The initial employment of the hand lens is partly to counter the wealth of microscopical petrographical data that can obscure important gross similarities in a characteristic wood for the trees syndrome, but mainly to provide a framework for these detailed data, as exemplified in Tables 8–9.

Thin-section petrography is the most effective method for provenancing the inorganic, non-plastic components of ceramics but is of little use in assigning an origin for the clay component. For clays the very difficult task of provenancing them is better attempted by chemical analysis.

Results, both in terms of inter-site comparisons and provenance are always constrained by the numbers of samples. Ideally a minimum of six and preferable ten sherds for each ware type per locality should be collected with greater numbers from user sites than from manufacturing sites.

Methodology

A standard thin section was prepared from each of the pottery sherds and was investigated using a x20 hand lens and the Geological Society of America rock-color chart. The firing colour was obtained by placing the thin section onto white paper and, using natural, north-facing light, comparing the gross colour with the rock-colour chart. Opaques were investigated by holding the slide at approximately 30^{O} to sunlight and looking across the cover slip. True, black opaques were distinguished from very dark red, internally fine-grained, mudclasts by this method. Since both classes of material appeared opaque when viewed orthogonally against a bright light inclined viewing is needed.

Grain size, grain distribution, and a rough identity of the non-plastics were noted, as were details of void spaces and opaques. Grain size was determined using a linear scale calibrated to 0.1mm alongside a standard sedimentalogical grain size scale provided by Geo Supplies Ltd. The results were tabulated and are given in Tables 8–9.

Each thin section was investigated using transmitted light petrography in plane polarised and crossed polarised light using x6.3 and x12.5 and x25 objectives with x12.5 eye pieces giving overall magnifications of x80, x155 and x310.

The petrographical characteristics of Cistercian-type and Midlands purple wares from the same locality differ from each other in significant ways and so have been treated separately. This is in line with Vince (2007) who, on a reasonable number of samples and with geochemical data, has suggested that at Ticknall Cistercian-type and Midlands purple wares were manufactured from different clays. The sherds were divided into Cistercian-type and Midlands purple and each type was then studied in ascending numerical order of sample number.

The emphasis of the report is on providing detailed petrographical characterisation of the sherds. A very tentative attempt at relating fabrics from production and consumption sites is made but the low numbers of samples from many sites significantly limits the robustness of this.

General petrographical characteristics of the Midlands ceramic material

In the present study of Midlands Cistercian-type and Midlands purple pots most non-plastics are silica-rich, either mono- or polycrystalline quartz accompanied by varying amounts of rock clasts and minor to trace amounts of feldspar, mainly potassium feldspar. With a hand lens monocrystalline quartz, void spaces and coarse-grained polycrystalline quartz appear to be clear in appearance, as do unaltered feldspar, hence distinguishing between monocrystalline and polycrystalline quartz is difficult. Altered feldspars appear pale-coloured and cloudy, as do many fine-grained feldspathic and micaceous rocks. Other rocks are cloudy and coloured. Tables 8–9 demonstrate very well the lack of real discrimination between silica-rich clasts other than in their size.

With the polarising microscope a far greater resolution is possible and the non-plastics resolved into a number of classes and sub-classes, as follows.

Quartz – monocrystalline quartz shows straight extinction or strained extinction and can display authigenic quartz overgrowths. All these are general indicators of their origins and hence have a provenance value in addition to being discriminatory. Quartz with straight extinction is usually first generation and is often igneous (granitic); quartz with inclined extinction is deformed/strained and so mainly metamorphic. As the origins of polycrystalline quartz clasts are manifold they are many types, each with their own characteristics. Amongst them are the following:

Sedimentary rocks include, with increasing internal grain size, chert, siltstone and sandstone.

Metamorphic rocks include meta-sandstone/quartzite, stretched quartz and serrated quartz or regular, quartz mosaics.

Volcanic/igneous rocks include rhyolite and vein quartz.

Feldspar – with a hand lens feldspars are recognised by their rectangular shape and by being cloudy, but untwinned, individual feldspar minerals cannot be discriminated further into their major classes, the plagioclase group and alkali feldspar group. The relative amount of plagioclase to alkali feldspar is an important discriminatory tool in both igneous and sedimentary rocks and, like quartz, different feldspars have different origins, so is a very useful provenance tool. Polycrystalline feldspathic rocks include felsite and are volcanic/fine-grained igneous in origin.

Opaques – as the name suggests, these appear black and allow no light through with either a hand lens or under the petrological microscope in plane polarised light. They comprise a mixture of materials, these include true opaque minerals, mainly metal oxides and sulphides; clays cemented by fine-grained iron- and manganese-rich minerals (these are normally haematite and limonite but can include manganese oxides/hydroxides (wad)); discrete plant and burned-out plant matter; metal working slag; and very fine-grained, organic-rich clays. Many opaques yield little information that is of importance to ceramic studies but recognition of anthropogenic components, namely slags and overfired clay, has significance, as does the type of organic matter. Opaques are normally identified using reflected light petrography using polished thin sections; transmitted light petrography is of very limited use for this material.

Rock clasts – rocks are mainly sedimentary (polycrystalline quartz) but also fine-grained siltstone, mudstone and limestone; or metamorphic (quartzite, stretched quartz and quartz mosaics) but including fine-grained mica-rich rocks (phyllite); or volcanic as fine-grained feldspathic rocks, basalt or intrusive as quartz-feldspar granite. Rocks are the most useful clasts in terms of discrimination and provenance. With a hand lens colour, transparency and size and internal grain size are the only easily distinguished properties of rock clasts (Tables 8–9).

Detailed petrographical report: archive report

The archive is divided into Cistercian-type and Midlands purple wares and is recorded in advancing sample number for each class of ware.
Where a polished thin section has been investigated it follows the main transmitted light petrographical description of that sample.

Macroscopical descriptions of the thin section complement Tables 8–9 and can be read alongside the macroscopic sherd descriptions given elsewhere.
The microscopical descriptions are divided into the main paste or rarely pastes 'the main body of the pot' followed by descriptions of any glaze.

Cistercian-type ware

Wednesbury High Street.

Macroscopical description 1-1

Sherd – unavailable.

Thin section
The pot has fired to a uniform, pale reddish brown (10R 5/4 on the Geological Society of America rock-color chart).

A clean clay carries <<0.1mm diameter quartz grains. Rare and irregularly distributed silicate grains are 0.1 to 0.3mm and sparse opaques are up to 0.5mm in diameter.
A thin glaze is 0.1–0.2mm thick.

Microscopical description 1-1

The main body of the pot
A reddish brown clay carries fine-grained quartz, rare phyllosilicates including brown ?biotite and chlorite together with larger, rounded to sub-angular, non-plastics that exhibit a tight size range and are dominated by monocrystalline quartz.
Monocrystalline quartz grains, mostly show straight extinction and some have fluid inclusions, are accompanied by lesser amounts of unaltered and altered potassium feldspar plus rare, acidic plagioclase and lath-shaped muscovite.

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here, quartz shows strained extinction), sedimentary chert, vein quartz and rare ?phyllite (fine-grained quartz-mica). A single, lath-shaped opaque is present.

Void spaces are similar in size to the larger non-plastic grains.

The glaze
An isotropic glaze has rare, small, spherical gas bubbles and adventitious, rare zircon and quartz grains within it. Pale brown, anisotropic, acicular crystals radiate out from the main clay into the clear and inclusion-free glaze.

Polished thin section description 1-1

The main body of the pot
A clean, dark red clay carries fine-grained quartz, rare phyllosilicates, 40–60μm in length including pale brown ?biotites that have very fine-grained haematite pigment lying along their cleavage planes. Other components of the clay include 20–50μm diameter, altered iron titanium oxide minerals that now comprise fine-grained intergrowths between haematite and TiO_2 minerals; 5–20μm diameter, ex-framboidal pyrite (now fine-grained haematite); and 2–20 but up to 60μm diameter, pale-coloured TiO_2 minerals

Most of the non-plastics are monocrystalline, angular quartz grains many with straight extinction and some carry fluid inclusions together with minor amounts of rounded potassium feldspar and rare plagioclase.

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here, quartz shows strained extinction) and chert. A large quartzite clast is cut by a quartz vein carrying altered phyllosilicates up to 120μm in length that carry acicular haematite along their cleavage planes.

Rounded, 60–150μm diameter clasts carry dense, fine-grained haematite pigment and may be fired limonite-rich mudclasts – the firing having altered the limonite to haematite.

Void spaces are similar in size to the larger non-plastics but a thin, curved void may be burned out plant matter.

The clay is reddened by abundant, very fine-grained, <1μm long, haematite pigment accompanied by 2–20μm long, rare haematite laths.

The glaze
The glaze is 120–200μm wide and much is inclusion-free or carries rare, up to 10μm diameter, hexagonal, basal haematite plates and a single, 40μm diameter, ?adventitious haematite clast.

The clay-glaze junction is sharp. Locally, immediately next to the main clay a 40μm wide glaze zone has 20–30μm diameter gas bubbles and 10 x <1μm size, colourless, acicular crystals, these are very thin. This zone passes out into clear glaze.

Macroscopical 4-1

Sherd – unavailable

Thin section
The pot has fired to a uniform, medium light grey (N6 on the Geological Society of America rock-color chart).

The non-plastics in the pot are fairly evenly distributed and have a restricted size range. Fine-grained quartz is up to 0.1mm in diameter and rounded, rock clasts are up to 0.3mm in size. Voids are up to 1mm long.

The dark medium grey (N5) glaze is 0.1–0.2mm thick.

Microscopical 4-1

The main body of the pot
A brown, 'dirty', isotropic clay carries fine-grained quartz, rare phyllosilicates including pale brown ?biotite and chlorite together with larger, sub-rounded to sub-angular, non-plastics, that exhibit a tight size range and are dominated by monocrystalline quartz.

Monocrystalline quartz grains, most showing straight extinction and some with fluid inclusions, are accompanied by rare, acidic plagioclase and potassium feldspar including microcline.

Rock fragments, less abundant than single mineral grains, comprise polycrystalline quartz that includes meta-sandstone/quartzite (here, quartz shows strained extinction), fine-grained, metamorphic, stretched quartz, and sedimentary chert.

Void spaces are irregular in shape.

The glaze
The main clay immediately adjacent to the glaze has an increased number of gas bubbles. Pale brown, anisotropic, acicular crystals within a brownish matrix radiate out from the clay into a clear, inclusion-

free glaze that carries large spherical gas bubbles and a hexagonal, orange brown phase (probably basal haematite crystals). Some of these crystals lie on the surface of the glaze. Very minor amounts of an unidentified, brown, equant, semi-opaque phase are present.

Macroscopical 5-1

Sherd – unavailable

Thin section.
The pot has fired to a uniform, medium light brown (5YR 5/6 on the Geological Society of America rock-color chart). A very light grey (N8), 5mm thick, fired clay is present on the rim of the sherd.

The non-plastics are fairly evenly but sparsely distributed and have a restricted size range. Fine-grained quartz is up to 0.1mm in diameter and rare, clasts are up to 0.2mm in size. Voids are up to 0.7mm long.

Pale-fired areas have the same paste as the main brown fired clay.
The glaze is 0.1–0.2mm thick.

Microscopical 5-1

The main body of the pot.
The pot has a faint planar fabric. A reddish brown, 'dirty', isotropic clay carries fine-grained quartz; rare, pale brown phyllosilicates, together with larger, sub-rounded to sub-angular, non-plastics that exhibit a tight size range and mainly comprise monocrystalline quartz.

Monocrystalline quartz grains, most with straight extinction, are accompanied by rare plagioclase and slightly altered potassium feldspars including microcline.

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here, quartz shows strained extinction); fine-grained, metamorphic stretched quartz; vein quartz, and rounded sedimentary chert. Quartz in a single clast carries fine-grained ?relict carbonate.

The light-coloured paste is petrographically identical to the reddish brown fired clay.

The glaze
Next to the reddish brown fired clay, thin, very poorly developed, pale brown, anisotropic, acicular crystals radiate into the isotropic glaze that carries rare, spherical gas bubbles and very rare, single, adventitious quartz grains.

However, the glaze next to the pale-fired clay comprises anisotropic, radiating laths showing first order interference colours (?feldspar/mullite).

Polished thin section 5.1 – microscopical

The main body of the pot
The clay carries sparse, angular to rounded non-plastics including quartz and 60µm long phyllosilicates with fine-grained haematite laths lying along their cleavage planes; 20–60µm diameter, unzoned, rounded zircon; 20µm diameter, brown rutile; abundant, 20–40µm diameter haematite-TiO_2 intergrowths after altered iron titanium oxide minerals (including ilmenite) and 1–5 and 10–30µm diameter, pale-coloured TiO_2 minerals.

Monocrystalline, rounded to subhedral quartz is accompanied by lesser amounts of rounded potassium feldspar including microcline and a single, 120µm long leucoxene (a TiO_2 boxwork).

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz and very fine-grained chert.

Small, 20–100µm diameter, fine-grained haematite pigment patches may be fired limonite-rich mudclasts – the firing having altered (dehydrated) the limonite to haematite. However, a single, 100µm diameter clast may comprise haematite pseudomorphs after pentagonal dodecahedral pyrite crystals.
The clay is red due to the presence of abundant, very fine-grained, <1µm long, haematite pigment that is accompanied by rare, 20–40µm long, lanceolate haematite crystals.

The glaze
The glaze is up to 140µm wide and has a sharp junction with the main clay. Most of the glaze is clear and inclusion-free but locally, immediately next to the main clay a 60µm wide zone carries abundant <1–2µm diameter, euhedral haematite. Within the main, clear body of the glaze, haematite, displaying its characteristic, deep red internal reflections, is irregularly distributed, occurring in 10–40µm diameter patches of 1–2µm long pigment associated with trace amounts of 2–4µm diameter cubic ?magnetite. In addition, circular gas bubbles have a thin, internal rim comprising <1–1µm long haematite and minor amounts of lath-shaped haematite lie along the top surface of the glaze.

Wednesbury Town Centre

Macroscopical 9-2

Sherd – unavailable

Thin section
The pot has fired to a uniform, light grey (N7 on the Geological Society of America rock-color chart) but a light brown (5YR 5/6) fired area is present within the main clay. The non-plastics are fairly evenly and densely distributed and have a restricted size range. Fine-grained quartz is up to 0.1mm in diameter (<187µm so less than fine sand in terms of grain size) but larger, non-plastic clasts are up to 0.5mm in size. Voids are 1–2mm long. Both the brown and light grey-fired clays have the same fabric, hence, both are the same paste.

The glaze is between 0.2–0.4mm thick and is pale yellow.

Microscopical 9-2

The main body of the pot.
A brown, 'dirty', isotropic clay carries fine-grained quartz; rare, pale brown phyllosilicates and abundant, spherical voids although these are rare in the brown-fired paste. The clay carries larger, sub-rounded to sub-angular, non-plastics that exhibit a tight size range and are mainly monocrystalline quartz.

Monocrystalline quartz grains, most showing straight extinction and some with fluid inclusions or with authigenic quartz overgrowths are accompanied by rare, altered plagioclase and potassium feldspar including perthite.

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here quartz shows strained extinction); together with clast-supported sandstone; rounded, fine-grained chert and recrystallised fine-grained quartz mosaics. A single, volcaniclastic clast is present.

Large voids are irregular in shape and opaque areas with gas bubbles ?infill some of these void spaces. Trace amounts of glaze are present within the main clay close to the pot surface.

The glaze
Petrographically the glaze shows no difference when next to the dark grey- or brown-fired clays. Very short, thin pale brown, anisotropic, acicular crystals radiate from the clay into the glaze (?feldspar/mullite) associated with rare, small hexagonal basal ?haematite plates. The isotropic glaze has rare spherical gas bubbles and is inclusion-free apart from single, ?adventitious quartz grains.

Macroscopical 10-2

Sherd – unavailable

Thin section
The pot has fired to a uniform, medium light grey (N6 on the Geological Society of America rock-color chart).

The non-plastics in the pot are fairly evenly distributed and have a restricted size range. Fine-grained quartz in the clay is up to 0.1mm in diameter. Voids are up to 1–1.5mm long and opaque areas are very rare. The clay next to the glaze carries abundant gas bubbles. The glaze is colour banded and is 0.1–0.4mm thick.

Microscopical 10-2

The main body of the pot
A brown, 'dirty,' locally silty, isotropic clay carries fine-grained quartz, very rare, pale brown phyllosilicates (?biotite) together with larger, sub-rounded to sub-angular, non-plastics that exhibit a tight size range and are mainly single quartz grains.
Monocrystalline quartz grains, many showing strained extinction and some with abundant fluid inclusions are accompanied by rare plagioclase and potassium feldspar.

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here quartz shows strained extinction), fine-grained 'chert' and vein quartz/recrystallised silica. A single, banded rhyolite/man-made glass clast is present.
Void spaces are irregular in shape.

The glaze
The glaze next to the main clay is browner and has pale brown, radiating, anisotropic acicular crystals (?feldspar/mullite) but away from the clay the glaze is clear, isotropic but has rare, spherical gas bubbles and adventitious quartz grains within it.

Burslem Market Place

Macroscopical 21-6

Sherd – unavailable

Thin section
The pot has fired to a uniform, yellowish grey (5Y 8/1 on the Geological Society of America rock-color chart).

The non-plastics in the pot are sparsely but fairly evenly distributed and have a restricted size range. Fine-grained quartz is <<0.1mm in diameter and rare, rounded, rock and mineral clasts are up to 0.2mm in size. Linear voids are up to 2mm long. The pale yellow glaze is 0.2–0.3mm thick.

Microscopical 21-6

The main body of the pot
The pot has a planar fabric. A dark brown, 'dirty', isotropic clay carries fine-grained, angular quartz, very rare, pale brown phyllosilicates (?biotite) together with larger, sub-rounded to sub-angular, non-plastics that exhibit a tight size range and are mainly single quartz grains.

Monocrystalline quartz grains include larger grains with strained extinction and some with abundant fluid inclusions.

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz that includes fine-grained chert and vein quartz/recrystallised silica. Very fine-grained, rounded, micrite/mudstone clasts and rounded opaques are present, as is a single, pale brown ?bone fragment.

Void spaces are linear and lie along the fabric.

The glaze
The glaze next to the clay carries very fine-grained gas bubbles and long, acicular, colourless crystals with first order interference colours (?feldspar/mullite) that radiate into the main isotropic glaze that has larger gas bubbles and rare, adventitious quartz grains.

Polished thin section 21-6 – microscopical

The main body of the pot
The clay has linear voids and rare, larger rock clasts.

A dark brown clay carries 30–80µm diameter, altered iron titanium oxide minerals that now comprise pale-coloured to orange TiO_2 phases; rare, 30µm diameter magnetite and discrete, 20–60µm diameter, pale-coloured TiO_2 minerals.

Abundant, rounded, 80–>200µm diameter, fine-grained haematite pigment patches may be fired limonite-rich mudclasts; the firing having altered the limonite to haematite. Other opaque clasts comprise quartz grains within a 2–10µm wide haematite cement, or are intergrowths of fine-grained haematite and TiO_2 minerals.

The glaze
The glaze is 160µm wide and the first 100µm closest to the main clay has abundant 10–20µm diameter gas bubbles, this passes out into a zone with 40–80 x <1µm tabular to acicular silicate crystals with straight extinction and first order interference colours suggesting they are mullite rather than feldspar. Locally, the glaze immediately next to the main clay carries 20–40µm diameter clusters of blebby ?magnetite and only trace amounts of haematite and may be altered ex-iron titanium oxide minerals. Inclusion-free portions of the glaze carry rare, up to 200µm diameter, gas bubbles.

The rarity of haematite in this glass is noteworthy and may well be of significance.

Macroscopical 22-6

Sherd – unavailable.

Thin section
The pot has fired to a uniform, medium grey (N6 on the Geological Society of America rock-color chart).

The non-plastics are fairly evenly and densely distributed and have a restricted size range. Rock clasts are polylithic and 0.1–0.3mm in diameter, and 0.5–1mm size opaques are common. The glaze is <0.1mm thick.

Microscopical 22-6

The main body of the pot
A brown, 'dirty,' isotropic clay carries fine-grained quartz and rare phyllosilicates together with larger, sub-rounded to sub-angular, non-plastics that exhibit a tight size range and are dominated by mono- and polycrystalline quartz alongside significant amounts of rounded, opaque matter.

Monocrystalline quartz grains, most showing straight extinction and some with fluid inclusions are accompanied by rare, plagioclase and rounded potassium feldspar grains including perthite.

Rock fragments are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (the quartz here has strained extinction), quartz-chert clasts cemented by opaques, and rounded, fine-grained chert.

Rounded, opaque areas show ?shrinkage cracks, enclose fine-grained quartz and have spherical voids (?gas bubbles). These may be organic rather than metal oxide/hydroxide-rich clay masses.

A single rounded ?slag clast is present.

The glaze
Very little glaze is present if at all and may have been lost during manufacture of the thin section. It comprises a very thin, isotropic glaze with very small gas bubbles.

Macroscopical 23-6

Sherd – unavailable.

Thin section
The pot has fired to a uniform brownish orange (5YR 4/1 on the Geological Society of America rock-color chart).

Non-plastics are rare and <<187µm in diameter. Opaques are up to 0.5mm in size and linear voids are 1mm long.

A pale yellow glaze is 0.2–0.3mm thick.

Microscopical 23-6

The main body of the pot
A dark, isotropic clay carries fine-grained, angular quartz and very rare phyllosilicates including muscovite together with sparse, opaque matter.

Rare, monocrystalline quartz grains, many with straight extinction, are accompanied by trace amounts of potassium feldspar.

Rock fragments, even less abundant than single grains, comprise fine-grained meta-sandstone/quartzite and chert.

Rounded, opaque matter shows ?shrinkage cracks and encloses fine-grained quartz. These may be organic rather than metal oxide/hydroxide-rich mudclasts.
Void spaces are linear in shape.

The glaze
The glaze is zoned and is the most complex of any of the Cistercian-type ware glazes.
Immediately next to the clay a thin, pale brown, isotropic glaze passes out into a zone with very, very fine-grained opaques succeeded by a thin, clear, isotropic zone with abundant, small gas bubbles. Most of the glaze comprises fine-grained opaques intergrown with lath-shaped ?mullite (?hollow laths with first order interference colours) or feldspar crystals. The very outer part of the glaze is brown-stained.

The glaze has rare, ?adventitious quartz grains within it.

Burslem School of Art

Macroscopical 31-8

Sherd – unavailable.

Thin section
The pot has fired to a uniform, medium grey (N5 on the Geological Society of America rock-color chart).

The non-plastics are evenly distributed and have a restricted size range. Fine-grained quartz is <0.1mm in diameter. Linear voids are up to 1.5mm long.

Adhering to the glaze is a black clay (N1) this has a very different paste/fabric to the main pot. The non-plastics are quite sparsely, but evenly, distributed, and are 0.2–0.4mm in diameter.

The pale yellow brown (10YR 6/2) glaze is 0.2–0.7mm thick.

Microscopical 31-8

The main body of the pot – paste/fabric 1
A dark, isotropic clay carries fine-grained quartz, rare phyllosilicates including ?biotite together with larger, sub-rounded to sub-angular, non-plastics that exhibit a tight size range and are mainly angular to sub-rounded, single quartz grains most with straight extinction.

Rock fragments, less abundant than single grains, are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here, quartz shows strained extinction), fine-grained, metamorphic, stretched quartz, and sedimentary chert. Very fine-grained quartz-feldspar-rich rocks may be volcaniclastics.

Void spaces are irregular in shape.

Paste/fabric 2 – black clay
A different paste adheres to the outside of the glaze. This clay is clean, very dark and carries sparse, sub-angular to sub-rounded meta-sandstone/quartzite clasts.

The glaze
The glaze is zoned. A very dark brown zone carrying very, very fine-grained ?haematite next to the clay passes out into a clear zone with large gas bubbles and rare, adventitious quartz grains. Elsewhere, the glaze touching the main clay has very fine-grained, equant ?magnetite passing out into a zone with radiating feathery and skeletal, acicular haematite. In places a thin ?haematite-rich layer coats the glaze surface.

Macroscopical 32-8

Sherd – unavailable.

Thin section
The pot has fired to a uniform pale brown (5YR 5/2 on the Geological Society of America rock-color chart). The non-plastics are evenly and quite densely packed, they have a restricted size range. Fine-grained quartz is up to 0.1mm in diameter, rounded rock clasts are up to 0.2mm in size, and large opaque areas are up to 1mm in diameter. Voids are up to 0.7mm long.

The dark yellow orange (10YR 6/6) glaze is 0.2–0.3mm thick.

Microscopical 32-8

The main body of the pot
A black, isotropic clay carries rare, pale brown phyllosilicates together with larger, sub-rounded to sub-angular, non-plastics that exhibit a tight size range and are mainly single quartz grains.

Monocrystalline quartz grains, most showing straight extinction, are accompanied by rare, rounded potassium feldspar.

Rock fragments are approximately as abundant as the single grains. They are varied in lithology but are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here quartz shows strained extinction), much fine-grained chert/?rhyolite and vein quartz/quartz vuggy infill. Fine-grained quartz-feldspar intergrowths may be volcanic clasts. A single, rounded clast may be haematite pigment-rich clay.

A thin, clay-rich layer is present.

Rounded, opaque matter shows ?shrinkage cracks and encloses voids after ?fine-grained quartz. These may be organic rather than metal oxide/hydroxide-rich mudclasts.

The glaze
A dark brown glaze with very fine-grained fibrous ?haematite and very small, equant ?magnetite passes out into a clear, pale brown, isotropic glaze carrying spherical gas bubbles and rare, ?adventitious quartz and rounded opaques.

Polished thin section 32-8

The main body of the pot
The clay carries fine-grained polycrystalline quartz and chert.

A black, isotropic clay carries 10–120 but up to 200µm diameter, altered iron titanium oxide minerals (probably titanomagnetite and ilmenite) comprising fine-grained haematite and TiO_2 mineral intergrowths; 40µm diameter, zoned zircon and discrete, pale-coloured TiO_2 including 60–80µm diameter leucoxene.

Abundant, 40–140µm diameter, fine-grained haematite-rich clasts have poorly crystalline haematite associated with rare, pale-coloured TiO_2 grains in them. Other clasts comprise quartz grains cemented by haematite pigment associated with 1–2µm diameter magnetite. Very fine-grained, 1–5µm long TiO_2 grains are widespread and very fine-grained haematite pigment gives the clay its colour.

The glaze
The 80–140µm wide glaze is complex although much is inclusion-free.
The main clay immediately next to the glaze is 'cleaned' of any fine-grained haematite pigment and the clay-glaze junction is sharp. A 20–60µm wide zone immediately next to the main clay carries abundant very fine-grained ?haematite with brown/yellow internal reflections. Elsewhere, close to the clay, within the cloudy yellow brown glaze, rare, 5–40µm diameter, orange to brown ?TiO_2 grains occur. These initial zones pass out into one with up to 20 x <1µm size, acicular haematite before finally passing out into a clear glaze with very rare haematite, some occurring as, up to 120µm diameter, clusters of 1–2µm long crystals. Gas bubbles are abundant.

Nuneaton Chilvers Coton

Macroscopical 42-10

Sherd – unavailable.

Thin section
The pot has a 1mm thick, black (N1 on the Geological Society of America rock-color chart), inner rim but most of the pot is a moderate brown (5YR 5/4). The non-plastics are fairly sparsely but evenly distributed and have a restricted size range in a clean clay. Rounded rock clasts are 0.3–0.4mm in size.

The pale yellow glaze is 0.1–0.3mm thick.

Microscopical 42-10

The main body of the pot
A black clay carries rare, pale brown phyllosilicates together with larger, rounded to sub-angular, non-plastics that exhibit a tight size range and are mainly single quartz grains.

Monocrystalline quartz grains, many with straight extinction and some with ?syntaxial overgrowths, are accompanied by rare, rounded potassium feldspar.

Rock fragments, less abundant than single grains, vary in lithology but are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here quartz shows strained extinction), serrated quartz, rounded sandstone and fine-grained quartz mosaics. Fine-grained, polycrystalline feldspathic rocks and phyllite (foliated fine-grained quartz-biotite) are rare.

Rounded opaque matter with ?shrinkage cracks, and large and locally linear voids are present in the clay.

The glaze
The glaze is complex. A glaze with very fine-grained, equant opaques (?magnetite) and small gas bubbles passes out into a browner glaze with radiating, acicular crystals (?haematite) and finally into a clear glaze. Locally the glaze with the fine-grained opaques and browner glaze are anisotropic with crystals showing first order colours and ?twinning suggesting feldspar.

Polished thin section 42-10 – microscopical

The main body of the pot
A black clay carries rare, pale brown phyllosilicates up to 120µm in length with acicular ?haematite along their cleavage planes; 20–40µm diameter, unzoned zircon; very rare, 30µm diameter ?chromite; 60µm diameter magnetite altering to haematite; 20–40µm diameter, altered iron titanium oxide minerals (including titanomagnetite and ilmenite) that now comprise fine-grained haematite and pale-coloured TiO_2 minerals; 10–30µm long, discrete haematite laths and 2–20 and 10–80µm long TiO_2 laths. Rare, 20µm diameter ex-pyrite framboids are now altered to haematite.

Larger, sub-angular, non-plastics exhibit a tight size range and are dominated by monocrystalline quartz accompanied by polycrystalline quartz clasts including quartz arenite; altered feldspathic rocks are also present.

Rounded, fine-grained haematite clasts are 20–200µm in diameter and comprise fine-grained haematite pigment within clay and may be fired (oxidised/dehydrated) limonite-rich mudclasts.

The glaze
The glaze is complex, up to 150µm wide and has a sharp clay-glaze junction. A 60µm wide zone carries 5–10µm diameter gas bubbles and very fine-grained, <<1µm diameter magnetite increasing in grain size away from the main clay up to 5µm; this magnetite is associated with minor haematite. This zone passes out into a 40µm wide zone where the opaques have the same size as the inner zone but have orange to red internal reflections. The final clear zone, up to 60µm in width, carries 20–80 x 1µm size, curved haematite 'laths' (hexagonal basal plates seen end on). Some of these basal plates, up to 30µm in size, lie along the upper surface of the glaze, other haematites in this surface layer look skeletal and resembles magnetite in shape.

Macroscopical 44-10

Sherd – unavailable.

Thin section
The pot has fired to a uniform moderate brown (5YR 5/4 on the Geological Society of America rock-color chart).

The non-plastics are fairly densely and evenly distributed and have a restricted size range. Fine-grained quartz is up to 0.1mm in diameter and single clasts are up to 0.3mm in size. Voids are up to 0.5mm long.

The pale yellow glaze is 0.3–0.5mm thick.

Microscopical 44-10

The main body of the pot
A very dark brown clay carries rare, pale brown phyllosilicates (?chlorite) together with abundant, larger, rounded to sub-angular, non-plastics that exhibit a tight size range and are mainly single quartz grains.

Monocrystalline quartz grains, many with straight extinction and some with ?syntaxial quartz overgrowths are accompanied by rare, rounded plagioclase and potassium feldspar including microcline and trace amounts of zircon.

Rock fragments, less abundant than single grains, vary in lithology but are dominated by polycrystalline quartz that includes meta-sandstone/quartzite (here quartz shows strained extinction), rounded sandstone, limonite-cemented sandstone, serrated quartz and fine-grained quartz mosaics. Fine-grained, polycrystalline feldspathic rocks (felsite), quartz-potassium feldspar igneous rocks and phyllite (fine-grained foliated quartz-biotite) and a litharenite comprising quartz, sandstone and potassium feldspar clasts are rare.

Rounded or ?euhedral, opaque grains may be oxidised pyrite and are widespread.
Voids in the clay are irregular in shape.

The glaze
The glaze varies, some just comprising clear glaze with gas bubbles concentrated towards the clay-glaze junction. Elsewhere, the glaze carries very fine-grained, equant opaques (?magnetite) and gas bubbles, and this passes out into a glaze with acicular, opaque crystals (haematite) that may have oxidised to limonite and finally into a clear glaze with rare ?haematite laths. Locally the isotropic glaze carries gas bubbles and adventitious quartz grains.

Polished thin section 44-10 – microscopical

The main body of the pot
A very dark brown clay carries rare, pale brown phyllosilicates up to 200 x 30µm in size with ?haematite laths along their cleavage planes; 20–30µm diameter, unzoned zircon; 10–80µm diameter, altered iron titanium oxide minerals (including ilmenite) that are now replaced by fine-grained, pale-coloured TiO_2 minerals; 5–10µm long, discrete haematite laths and 2–10 and 10–40µm long, pale to orange-coloured TiO_2 laths and 20–40µm diameter leucoxene.

The clay is red-brown due to abundant, very fine-grained, (<<1–2µm long) haematite pigment.

Rounded, fine-grained haematite-rich clasts are 40–160µm in diameter and comprise fine-grained haematite pigment within clay and may be fired/oxidised limonite-rich mudclasts; or quartz cemented by poorly crystalline haematite or pseudomorphs after pyrite.

The glaze
The glaze is complex and varies along its length, however the relative relationships between the zones are retained. The glaze immediately next to the main clay is inclusion-free, this very thin zone passes out into a zone with abundant, very fine-grained, <1µm diameter magnetite but locally up to 5µm in size showing minor martitisation (crystallographically controlled alteration to haematite). This zone in turn passes out into one with up to 30µm long haematite laths with brown internal reflections (some skeletal haematite may be oxidised magnetite) and finally into a clear glaze.

Small, 1–10µm long haematite laths with very red internal reflections lie parallel to the upper surface of the glaze or form internal rims to gas bubbles within the glaze.

Rare, pale brown, 10–40µm diameter ?TiO_2 mineral clusters are present in the glaze.

Rare adventitious quartz incorporated into the glaze shows no chemical reactions with it.

Leicester Austin Friars

Macroscopical 75-19

Sherd – unavailable.

Thin section
The pot has fired to a uniform pale reddish brown (10R 5/4 on the Geological Society of America rock-color chart) but has a thin, pale yellow brown (10YR 7/2) fired clay lens within the main clay.

A very clean clay carries <<0.1mm diameter quartz grains and very sparse, rounded quartz up to 0.2mm in diameter.

A thin glaze is up to 0.1mm thick.

Microscopical 75-19

The main body of the pot
A dark clay carries fine-grained, angular quartz, rare plagioclase and very rare, pale brown phyllosilicates including muscovite, together with very sparse, opaque matter.
The non-plastics comprise rare, monocrystalline quartz grains, and many have straight extinction, some are euhedral or carry fluid inclusions, accompanied by minor amounts of unaltered and altered potassium feldspar including microcline.

Rock fragments, even less abundant than single grains, comprise fine-grained meta-sandstone/quartzite and chert.

Void spaces are linear in shape and some may have black, burned out organic matter in them.

Larger voids enclose brown ?fibres (resembling bacterial chains). A deep blue-green amphibole is present on the surface of the section but is probably adventitious, and caused during the manufacture of the slide.

The glaze
The glaze is thin but zoned. A brown and turbid glaze passes out into a zone with pale-brown, acicular, radiating crystals showing first order interference colours (?feldspar/mullite) and finally into a clear isotropic glaze.

Macroscopical 77-19

Sherd – unavailable.

Thin section
The pot has fired to a uniform, pale reddish brown (10R 5/4 on the Geological Society of America rock-color chart).

A clean clay has <<0.1mm diameter quartz and rare, larger grains up to 0.2mm in diameter. Siltier, pale-fired areas are 4mm x 1mm in size and are filled with fine-grained, angular quartz. Rare, rounded rock clasts are up to 0.5mm in size.

A thin glaze is up to 0.2mm thick.

Microscopical 77-19

The main body of the pot
A dark red clay carries fine-grained, angular quartz and very rare, pale brown phyllosilicates including muscovite together with sparse, rounded, opaque matter. Pale-fired layers appear to be siltier than the main clay and carry fine-grained, angular quartz with rare chlorite and sandstone clasts.

The non-plastics comprise monocrystalline quartz grains, many showing straight extinction accompanied by trace amounts of potassium feldspar and lath-shaped muscovite.

Rock fragments, even less abundant than single grains, comprise fine-grained meta-sandstone/quartzite (here quartz shows strained extinction) and fossiliferous, sedimentary chert.

Void spaces are partially or fully infilled with ?later calcite and more calcite adheres to the edge of the sherd.

The glaze
The glaze is zoned with a thin zone of anisotropic, acicular crystals radiating out from the main clay: this passes out into a clear, isotropic glaze with rare gas bubbles.

Macroscopical 79-19

Sherd – unavailable.

Thin section
The pot has fired to a uniform medium reddish brown (10R 5/6 on the Geological Society of America rock-color chart).

A clay carries abundant, 0.1mm diameter grains and rare, unevenly distributed, rounded, single grains up to 0.3mm and rock clasts up to 0.5mm in size. Large opaque areas are 0.4–1.0mm in diameter. ?Vitrified areas are 0.4mm in size.

The glaze is 0.2mm thick.

Microscopical 79-19

The main body of the pot
A dark clay carries abundant, angular quartz and brown phyllosilicate laths.
The non-plastics comprise monocrystalline quartz grains many with straight extinction, accompanied by trace amounts of zoned, altered potassium feldspar and lath-shaped muscovite and biotite. Most of the quartz lies within a very restricted size range.

Polycrystalline quartz rock fragments, far less abundant than single quartz grains, comprise meta-sandstone/quartzite (here quartz shows strained extinction); sandstone with quartz and sandstone clasts in it; fine-grained sandstone/chert and a single, large, rounded micaceous sandstone (quartz arenite).

Rounded to irregular opaque areas carry quartz and rare void spaces are irregular in shape.

The glaze
The glaze is zoned with a zone of very fine-grained, equant opaques (?magnetite/haematite) passing out into a clear, isotropic glaze, that carries gas bubbles and a little ?adventitious quartz. Locally, areas of thicker clear glaze have thin, haematite laths close to the outer surface.

Bordesley Abbey

Macroscopical 94-24

Sherd – unavailable.

Thin section
The pot has fired to a uniform dark reddish brown (10R 3/4 on the Geological Society of America rock-color chart).

The clay is very clean with very sparse clasts up to 0.2mm in diameter; they include two rounded, ?glaze clasts up to 0.3mm in size. Linear voids are 1mm long.
The pale-coloured glaze is 0.4mm thick.

Microscopical 94-24

The main body of the pot
A dark red, very clean clay has trace amounts of fine-grained white mica and monocrystalline quartz.

Polycrystalline quartz rock fragments are also rare and comprise fine-grained sandstone and chert.

Rounded opaque areas are unevenly distributed and have shrinkage rims. Void spaces are irregular in shape.

Two rounded areas within the clay and one on the edge of the sherd next to the glaze comprise a mixture of lath-shaped phases with moderate interference colours and a very fine-grained matrix. These are not natural but their mineralogy is undetermined.

The glaze
The glaze is zoned. A glaze with large gas bubbles and very fine-grained, ?cubic opaques (?magnetite) passes out into a brown, isotropic glaze with brown, acicular opaques and hexagonal basal plates (?haematite). Locally the glaze has ?recrystallised and is now composed of pale brown, acicular, anisotropic crystals showing first order interference colours within an anisotropic matrix (?mullite/feldspar).

Remarks
The presence of ?glaze-rich areas/clasts within the main paste is very unusual.

Macroscopical 95-25

Sherd – unavailable.

Thin section
The pot has fired to a uniform moderate reddish brown (10R 4/6 on the Geological Society of America rock-color chart).

Fine-grained quartz is up to 0.1mm in diameter. The non-plastics are densely and fairly evenly distributed and have a restricted size range with rounded, single clasts up to 0.4mm in size and rounded opaques up to 0.5mm in diameter.

The pale yellow glaze is 0.1mm thick.

Microscopical 95-25

The main body of the pot
A dark clay carries abundant, angular quartz and minor amounts of a brown phyllosilicate ?biotite and muscovite.

The non-plastics comprise rounded to angular, monocrystalline quartz grains, many showing straight extinction, accompanied by lesser amounts of potassium feldspar. The quartz grains have a wide size range. Many potassium feldspar grains are rounded and have been partially lost during thin section preparation.

Polycrystalline quartz rock fragments, far less abundant than single quartz grains, comprise meta-quartzite (here quartz shows strained extinction), stretched quartz, zircon-bearing sandstone, chert/'meta-chert', fossiliferous chert, plus very rare felsite and ?granophyre/myrmekite.

Void spaces are irregular in shape and rounded opaque areas are abundant and have shrinkage rims.

The glaze
The thin glaze is isotropic. Initially the glaze carries very fine-grained equant and hexagonal, brown opaques (?haematite) aligned into thin trains/swirls passing out into a very pale brown, clean glaze. A little ?adventitious quartz and gas bubbles are trapped in the glaze.

Macroscopical 96-25

Sherd – unavailable.

Thin section

The pot has fired to a uniform, moderate reddish brown (10R 4/6 on the Geological Society of America rock-color chart).

The non-plastics are evenly distributed and have a restricted size range. Fine-grained quartz is up to 0.1mm in diameter, rounded, polylithic rock clasts are up to 0.5mm in size and rare, rounded opaques are up to 0.4mm in diameter.

The glaze is 0.1mm thick.

The main body of the pot
A dark clay carries abundant, angular quartz and brown phyllosilicate laths.

The non-plastics comprise sub-rounded to angular, monocrystalline quartz grains with a wide size range, many of which have straight extinction or enclose fluid inclusions and some of which have ?syntaxial quartz overgrowths. Lesser amounts of rounded potassium feldspar occur but have been partially lost during section preparation.

Medium grained, polycrystalline quartzose rocks fragments are abundant and comprise meta-quartzite (here quartz shows strained extinction), clast-supported sandstone and foliated sandstone, plus polycrystalline feldspathic rocks, felsite, very rare granophyre/myrmekite and ?tuff.

Void spaces are irregular in shape and rounded opaque areas have shrinkage rims.

The glaze
The glaze is isotropic and has very fine-grained, equant opaques lying in trains. Gas bubbles and rare ?adventitious quartz or polycrystalline quartz are trapped in the glaze.

Macroscopical 97-26

Sherd – unavailable.

Thin section
The pot has fired to a uniform dark yellow orange (10YR 6/6 on the Geological Society of America rock-color chart).

The clay is very clean and carries fine-grained, >0.1mm in diameter quartz, and rare, evenly distributed, 0.1–0.2mm diameter clasts.

The glaze is 0.2mm wide.

Microscopical 97-26

The main body of the pot
A dark red clay has trace amounts of fine-grained white mica, brown phyllosilicate and altered plagioclase plus slightly larger, angular, monocrystalline quartz and cleavage fragments of potassium feldspar. Larger grains are very rare.

Rare, polycrystalline quartzose rocks comprise meta-sandstone, chert and very rare phyllite.

Opaque areas are small and rounded and void spaces are linear in shape.

The glaze
The glaze is isotropic with trapped gas bubbles. There is a very thin reaction rim between the glaze and clay, and this is present as short, very fine, acicular crystals radiating into the glaze.

Macroscopical 101-26

Sherd – unavailable.

Thin section
The pot has fired to a uniform pale reddish brown (10R 5/4 on the Geological Society of America rock-color chart).

The clay is very clean and carries sparse, fine-grained, >0.1mm in diameter quartz grains. Rounded or less abundantly sub-angular grains, up to 0.5mm in diameter, have a restricted size range and are fairly evenly distributed. Angular rock clasts and rare opaque patches are 0.5mm and mudstone clasts are up to 0.2mm in diameter.

The glaze is 1.5mm thick on the sherd, but is 5.5mm thick as discrete samples. The latter has greyish green (10GY 6/2) bands in a moderate yellow (5Y 7/6) base.

Microscopical 101-26

The main body of the pot
A dark, reddish, clean clay carries minor, angular quartz and trace amounts of pale phyllosilicate.

The non-plastics are rounded to sub-angular and have a fairly restricted size range. They comprise monocrystalline quartz grains, and many have straight extinction and/or fluid inclusions, some have syntaxial quartz ?overgrowths, and one encloses acicular rutile; quartz grains are accompanied by rare potassium feldspar cleavage fragments, plagioclase and lath-shaped muscovite. Most of the quartz lies within a very restricted size range.

Polycrystalline quartzose rocks comprise meta-sandstone/quartzite and stretched quartz (quartz in both has strained extinction); clast-supported sandstone with quartz and chert clasts, or with quartz, potassium feldspar and zircon clasts; and chert. Tectonised sandstone/quartzite, quartz-potassium feldspar ‘granite’, metamorphic quartz-perthite and phyllite are rare.

Opaque areas are rounded but void spaces are thin and linear.

The glaze
The glaze is clear and isotropic, looks crazed and is colour banded. There is no reaction rim between glaze and clay but a little adventitious quartz and sandstone are trapped in the glaze.

Macroscopical 102-27

Sherd – unavailable

Thin section
The pot has fired to a uniform moderate reddish brown (10R 4/6 on the Geological Society of America rock-color chart).

The clay is clean and carries sparse, fine-grained, >0.1mm in diameter, quartz. Rare, sub-rounded grains up to 0.4mm in diameter have a restricted size range and are fairly evenly distributed. Brown limonite/mudstone clasts are up to 0.5mm in size and black opaques are 0.1–0.4mm in diameter.

The glaze is 0.1–0.3mm thick.

Microscopical 102-27

The main body of the pot
A dark reddish, clean clay carries minor amounts of very fine-grained, angular quartz and trace amounts of pale phyllosilicate ?chlorite.

The non-plastics are quite sparse and are rounded to sub-angular and have a fairly restricted size range. They comprise monocrystalline quartz grains, many have straight extinction and some have syntaxial quartz ?overgrowths; the quartz is accompanied by rounded to angular potassium feldspars including perthite.

Polycrystalline quartzose rocks comprise clast-supported sandstones, chert, 'chert/rhyolite', rare vein quartz and meta-sandstone/quartzite. In many of the rock fragments quartz has strained extinction.

Rare opaque areas are rounded to irregular in shape and enclose fine-grained quartz.

Void spaces are few but include a curved ?spine/shell.

The glaze
The thin, clear, isotropic glaze looks crazed. The glaze-clay junction is black and marked by very, very thin, acicular crystals radiating out into the main glaze. Gas bubbles and a little ?adventitious quartz are trapped in the glaze

Macroscopical 103-27

Sherd – unavailable.

Thin section
The pot has fired to a uniform moderate reddish orange (10R 6/6 on the Geological Society of America rock-color chart).

The clay is clean and carries very fine-grained, >>0.1mm in diameter, angular quartz. Sparse, rounded grains and rock clasts up to 0.5mm in diameter have a restricted size range. Rare opaques are 0.1mm in size.

A 3mm thick, clean glaze carries 0.2mm diameter air bubbles.

Microscopical 103-27

The main body of the pot
A dark reddish brown clay carries very fine-grained, angular quartz and trace amounts of a pale phyllosilicate ?chlorite/muscovite. Some clay layers are a little siltier than the main clay.

The non-plastics are quite sparse and are rounded to sub-angular and have a fairly restricted size range. They mainly comprise monocrystalline quartz grains, many showing straight extinction and some having syntaxial quartz ?overgrowths and so are euhedral. Quartz is accompanied by rounded to angular, altered, zoned plagioclase and potassium feldspar including microcline; some potassium feldspar has syntaxial feldspar overgrowths and others are cleavage flakes.

Polycrystalline quartz rocks are less common than single grains; they comprise meta-sandstone/quartzite (here quartz shows strained extinction), rounded, clast-supported sandstones, chert and 'chert with mica'. Very fine-grained acid volcanics (?tuffs) and phyllite (fine-grained foliated quartz-biotite) are present but uncommon.

Opaque areas are rounded and small. Void spaces are few but include a small ?spine/shell.

The glaze
The clay-glaze junction is thin and dark and has very thin, acicular crystals with first order interference colours radiating out from it into the glaze. Quartz grains are concentrated at this junction.

The other surface of the sherd has a very thin glaze with extremely fine-grained, equant opaques (?magnetite) passing out into clear isotropic glaze. Gas bubbles and a little adventitious quartz are trapped in the glaze.

Macroscopical 104-28

Sherd – unavailable.

Thin section

The pot has fired to a uniform moderate reddish brown (10R 4/6 on the Geological Society of America rock-color chart).

The clay carries sparse, <0.1mm diameter quartz; sparse, rounded clasts to 0.7mm and rare, fine-grained rocks up to 0.5mm in size. Pale-fired, thin, 0.1mm wide, silty layers are present. Rounded, 0.5–1mm diameter opaques are widespread but unevenly distributed. ?Carbonate up to 1.5mm in size is rare.

Microscopical 104-28

The main body of the pot
A dark reddish brown clay carries fine-grained, angular quartz and trace amounts of pale phyllosilicate ?muscovite and pale brown phyllosilicate ?biotite. Some pale-fired, clay layers are a little more silty than the main clay and carry abundant, angular, fine-grained quartz and mica.

The non-plastics are quite sparse and are rounded to sub-angular and have a fairly restricted size range. They mainly comprise monocrystalline quartz grains, and many show straight extinction or have fluid inclusions; this quartz is accompanied by potassium feldspar laths.

Polycrystalline quartzose rocks comprise meta-sandstone/quartzite (here quartz shows strained extinction), sandstones, chert and vein quartz. Very fine-grained acid volcanics (?tuffs) and felsite are present.

Opaque areas are rounded, vary in size and are irregularly distributed; some may be organic. Void spaces are irregular in shape.

The glaze
The glaze is zoned. A glaze with very, very, fine-grained opaques (?haematite) is overlain by thin, acicular crystals showing first order interference colours (?mullite/feldspar) passing out into clear, isotropic glaze that carries rare, larger opaques (?haematite).

Macroscopical 108-28

Sherd – unavailable.

Thin section
The pot has fired to a uniform moderate reddish orange (10R 6/6 on the Geological Society of America rock-color chart).

An extremely fine-grained clay carries <<0.1mm diameter quartz and sparse, rounded clasts up to 0.5mm in size. Pale-fired silty layers are 1mm long.

The glaze is 0.2mm thick.

Microscopical 108-28

The main body of the pot
A dark, reddish brown clay carries fine-grained, angular quartz and trace amounts of pale phyllosilicate (?chlorite/muscovite), biotite and plagioclase. Pale-fired clay areas have the same paste as the main pot.

The non-plastics are quite sparse and are rounded to sub-angular and have a fairly restricted size range. They mainly comprise monocrystalline quartz grains, and many show straight extinction and fluid inclusions; quartz is accompanied by rounded potassium feldspar including microcline.

Polycrystalline quartzose rocks are less common than single grains; they comprise meta-sandstone/quartzite, chert, and meta-mudstone cut by a thin quartz veinlet. Much quartz in the polycrystalline clasts has strained extinction and serrated grain boundaries.

Rare, opaque areas are small.

The glaze
A glaze with very thin, radiating, pale brown, anisotropic, acicular crystals passes out into a clear isotropic glaze. Gas bubbles and a little adventitious quartz are trapped in the glaze.

Ticknall

Macroscopical Ticknall AV 4270

Sherd – unavailable.

Thin section
The pot has fired to a uniform, moderate reddish brown (10R 4/6 on the Geological Society of America rock-color chart).

Abundant, fine-grained quartz is up to 0.1mm in diameter but larger, non-plastics are very sparse.

Microscopical Ticknall AV 4270

The main body of the pot
A dark red clay has abundant, angular to sub-angular quartz plus trace amounts of fine-grained white mica, brown phyllosilicate and potassium feldspar. The quartz has a very tight size range and many grains show strained extinction. Large single quartz grains are very rare.

Polycrystalline quartzose rocks are rare and comprise meta-sandstone, rounded, clast-supported sandstone, chert and fine-grained, recrystallised quartz mosaics.
Opaque areas are rounded and enclose quartz whereas void spaces are irregular in shape and vary in size.

The glaze
The clay-glaze junction is sharp and there is no reaction rim between clay and glaze. A 0.2mm thick, clear glaze encloses adventitious quartz grains but has no gas bubbles.

Macroscopical Ticknall AV 4278

Sherd – unavailable.

Thin section
The pot has fired to a uniform pale reddish brown (10R 5/4 on the Geological Society of America rock-color chart).

Abundant, fine-grained quartz in the clay is <<0.1mm in diameter. Larger, rock clasts are very sparse and up to 0.5mm in size.

Microscopical Ticknall AV 4278

The main body of the pot
A dark clay has abundant, angular to sub-angular fine-grained quartz plus trace amounts of a brown phyllosilicate. The quartz has a very tight size range and many grains show strained extinction.

Large, rounded quartz grains are very rare and have strained extinction.

Rare, polycrystalline quartzose rocks comprise rounded, fine-grained sandstone and chert; a single, fine-grained volcanic ?tuff with mica is present.

Opaque areas are rounded and enclose quartz whereas void spaces are large, linear in shape and vary in size.

The glaze

The 0.4mm thick, clear, yellow, isotropic glaze encloses adventitious quartz grains and large gas bubbles. There is no reaction rim between clay and glaze.

Midlands purple

Wednesbury High Street.

Macroscopical 11-3

Sherd – unavailable.

Thin section
The pot has fired to a 5mm thick, medium reddish brown (10R 4/4 on the Geological Society of America rock-color chart) clay alongside a 5mm thick, light brown paste.

Pale-fired silty layers are 0.2mm thick. The clay is clean but carries fine-grained, <<0.1mm in diameter quartz. Abundant, evenly distributed, sub-rounded to sub-angular, single grains and rock clasts are 0.5–1.0mm in diameter.

Black areas with gas bubbles may be overfired clay.

Microscopical 11-3

The main body of the pot
A dark clay with very thin, light-coloured siltier layers has small, angular to sub-angular quartz.

Larger, monocrystalline grains and rock fragments are rounded to sub-angular. They have a fairly restricted size range, are evenly distributed and are quartz dominated.

Large, rounded quartz grains have uniform or strained extinction and some show syntaxial quartz overgrowths. Rounded to tabular ?potassium feldspar (first order interference colours) has dark brown rims associated with gas bubbles; elsewhere potassium feldspar has been lost during the slide manufacture. No unaltered feldspar grains were recognised.

Polycrystalline quartzose rocks are widespread and comprise meta-quartzite (here quartz shows strained extinction); metamorphic stretched quartz; rounded, fine-grained sandstone, limonite-cemented sandstone, medium-grained sandstone and chert. ?Felsite and phyllite clasts are rare.

Opaque areas are rounded and some have ?burned out matter in their core; linear voids are common.

The glaze
A <0.1mm thick, ‘dirty’, turbid, isotropic glaze encloses ?adventitious quartz grains, gas bubbles and very fine-grained opaques; some are hexagonal with red-brown internal reflections (?haematite).

Macroscopical 14-3

Sherd – unavailable.

Thin section
The pot has fired to a very pale orange (10YR 8/2 on the Geological Society of America rock-color chart) core within a pale yellowish orange (10YR 8/6) margin. A very clean clay carries fine-grained quartz <<0.1mm in diameter. Larger, up to 0.4mm diameter, rounded, rock clasts are very rare. The pot has slightly siltier layers. Opaque and dark brown areas ?limonite/mudstone, 0.3–0.5mm in diameter, are evenly distributed; many are rounded and some may be oxidised pyrite.

A <0.1mm–0.3mm thick, opaque (N1) ?glaze has <0.1mm diameter clasts in it.

Microscopical 14-3

The main body of the pot
A dark clay has abundant, angular to sub-angular quartz plus trace amounts of a brown phyllosilicate including biotite. Different clay layers have fired to slightly different colours and rounded, pale-fired areas are present.

Large, rounded to sub-rounded quartz grains are very rare and have strained extinction. Infrequent, rounded to tabular ?potassium feldspar (first order interference colours) has dark brown rims or has been lost during the slide manufacture. No unaltered feldspar was recognised.

Polycrystalline quartzose rocks are rare and comprise rounded, fine-grained sandstone, recrystallised quartz mosaics, chert and 'chert' with mica. A single polycrystalline feldspathic rock is present.

Very small, rounded, brown ?clasts have very low interference colours and may be anthropogenic?

Opaques are common, small, rounded or euhedral in shape and may be oxidised pyrite framboids or pentagonal dodecahedral pyrite crystals.

Void spaces are rounded or linear in shape and are locally infilled with calcite.

The ?glaze
An opaque rim with a sharp junction with the main clay carries adventitious, fine-grained quartz and polycrystalline quartz and gas bubbles. This may be vitrified clay rather than a true glaze. Elsewhere, a very thin glaze carries very fine-grained opaques.

Wednesbury Market Place

Macroscopical 16-4

Sherd – unavailable.

Thin section
The pot has fired to a uniform greyish red (5R 4/2 on the Geological Society of America rock-color chart) but has a 3mm wide, medium reddish brown (10R 4/6), lens within it.

A clean clay has 0.1–0.2mm thick, pale-fired, silty layers and a 0.8mm long, similarly pale-fired lens. The main clay carries <0.1 diameter quartz; rare, larger, 0.3–0.5mm diameter clasts and numerous, rounded, 0.5–1.5mm size opaques.

A rounded, dark-fired rim is 2mm thick and has gas bubbles and 0.5mm diameter quartz clasts in it.

A 1mm thick, clear/turbid glaze has 0.5mm diameter ?adventitious quartz in it. Close to the clay the opaques are <<0.1mm in size.

Microscopical 16-4

The main body of the pot
A black, very dense clay has abundant angular to sub-angular quartz plus trace amounts of brown phyllosilicate and ?muscovite. This is most clearly seen in the pale-fired layers and lenses.

Larger, rounded to sub-angular quartz grains are rare and have syntaxial quartz ?overgrowths and strained extinction. Polycrystalline quartz-rich rock fragments are rare and comprise quartzite, sandstone with quartz and chert clasts and rare chert; felsite (fine-grained polycrystalline feldspar) is very rare.

Very small, rounded, brown areas with gas bubbles may be ex-potassium feldspar. No unaltered feldspar was recognised.

Most opaques are small, rounded or are euhedral and may be oxidised, pentagonal dodecahedral pyrite crystals.

Void spaces are rounded or linear in shape.

The glaze
A thick, isotropic, clear glaze carries abundant, fine-grained, euhedral opaques (?magnetite) some entrained in 'swirls'. Gas bubbles are concentrated close to the clay junction and have thin ?haematite inner linings. Both ?magnetite and haematite are present.

Macroscopical 17-4

Sherd – unavailable.

Thin section
The pot has fired to a uniform moderate reddish brown (10R 4/6 on the Geological Society of America rock-color chart).

A quite clean clay carries fine-grained, <0.1mm diameter quartz. Larger, sub-rounded to sub-angular rock clasts are fairly sparse, evenly distributed and up to 1.0mm in size. Rounded quartz grains and rare, rounded opaques are up to 0.7mm in size.

A 0.1mm thick, opaque rim has trapped gas bubbles in it.

It is unglazed.

Microscopical 17-4

The main body of the pot
A dark clay has angular to sub-angular quartz plus trace amounts of muscovite and brown biotite.

Larger, rounded to sub-angular quartz grains are sparse and enclose fluid inclusions, show strained extinction and some have ?syntaxial quartz overgrowths. Rounded to tabular ?potassium feldspar grains (first order interference colours) have dark brown rims accompanied by gas bubbles or have been lost during the slide manufacture. No unaltered feldspar was recognised.

Polycrystalline quartz-rich rock fragments are rare and comprise meta-quartzite (here quartz shows strained extinction); stretched quartz; sandstone with quartz and chert clasts; quartz mosaics and rounded chert; a single quartz and biotite-bearing, fine-grained, igneous rock clast is present.

Wednesbury Meeting Street

Macroscopical 20-5

Sherd – unavailable.

Thin section
The pot has fired to a uniform greenish grey (5GY 5/1 on the Geological Society of America rock-color chart).

Abundant, fine-grained quartz in the clay is <<0.1mm in diameter. Polylithic rock clasts are present and show a wide size range from 0.2–0.8mm in diameter. Rounded opaques, up to 0.5mm in diameter, are common but red mudstone clasts are rare.

A 0.2–0.4mm thick, yellow glaze has trapped gas bubbles in it.

Microscopical 20-5

The main body of the pot
A dark 'dirty' clay carries abundant, fine-grained, angular quartz and trace amounts of a pale phyllosilicate ?muscovite, zoned plagioclase and ?chlorite.

The non-plastics are sparse, rounded to sub-angular. They comprise monocrystalline quartz grains within a very restricted size range; many quartz grains enclose abundant fluid inclusions. Rounded, potassium feldspar including microcline is thinned and has small gas bubbles around it.

Polycrystalline, quartz-rich rock fragments are rare and comprise meta-sandstone/quartzite (here quartz has strained extinction), sandstone and brown chert. A single feldspathic igneous rock clast is present

Abundant opaque areas are rounded, some are dark fired clay, but others have shrinkage rims and may be organic.

Void spaces are abundant and a similar size and shape to the larger quartz/rock and opaques clasts.

The glaze
Much of the glaze is very thin, clear and isotropic and the junction between glaze and the main clay shows no reaction rim. Where the glaze is thicker and next to the main clay, it carries very, very fine-grained, equant opaques including laths and hexagonal basal plates of ?haematite.

Burslem Market Place

Macroscopical 26-7

Sherd – unavailable.

Thin section
The pot has fired to a uniform brownish grey (5YR 4/1 on the Geological Society of America rock-color chart).

A clean clay carries abundant, 0.2–0.5mm diameter clasts, which have a restricted size range. Sparse, sub-rounded opaques are 0.4–1.0mm across and evenly distributed and ?carbonate-rich areas, up to 3mm in size, are present.

A thin, black (N1) ?glaze is up to 0.2mm wide and has gas bubbles.

Microscopical 26-7

The main body of the pot.
A dark clay carries fine-grained, angular quartz and trace amounts of pale brown phyllosilicate and potassium feldspar. Alternating clay and thin silty clay layers are present and help to define a fabric.

The non-plastics are quite abundant and are rounded to sub-angular and have a fairly restricted size range. They mainly comprise monocrystalline quartz grains; many of these have fluid inclusions in them and show strained extinction.

Polycrystalline, quartz-rich rock fragments are far less common that single quartz grains. They comprise meta-sandstone/quartzite, chert and fine-grained quartz mosaics. Much polycrystalline quartz shows strained extinction. Other rock types are rare but include granophyre/myrmekite and foliated quartz-mica phyllite.

Small, rounded, brown areas with gas bubbles are present within the clay and visually resemble glaze.

Opaques are rounded to equant and have a wide size range.

Void spaces are abundant and linear, or have a similar size and shape to the larger quartz/rock and opaque clasts.

The glaze
The glaze is zoned. The main clay passes out into a ?vitrified clay that is paler in colour but has abundant gas bubbles (and looks like the material found in the body of the sherd), then into a dense glaze zone of thin, brown, radiating, anisotropic acicular crystals (but not ?mullite) passing out into a clear, isotropic glaze with infrequent acicular crystals. Locally very, very thin, radiating, acicular opaques are present as are rare, adventitious, single quartz grains.

Macroscopical 28-7

Sherd – unavailable.

Thin section
The pot has fired to a 3mm thick, brownish grey (5YR 4/1 on the Geological Society of America rock-color chart) alongside a 5mm thick, medium dark grey (N4).

The clay carries abundant, fine-grained <<0.1mm diameter quartz. Pale-fired silty layers are 0.1mm thick. Larger, rounded to sub-rounded clasts are fairly abundant and up to 0.5mm in diameter. Opaques/reddened, fine-grained mudclasts are rounded to irregular in shape and up to 1mm in diameter.

The sherd has a 0.1mm thick, black rim with fine- and coarse-grained quartz but no gas bubbles.

Microscopical 28-7

The main body of the pot
A dark red brown clay carries much, fine-grained, angular quartz and trace amounts of pale brown phyllosilicate.

The non-plastics are quite sparse and are rounded to sub-angular and have a fairly restricted size range. They mainly comprise monocrystalline quartz grains, and many carry fluid inclusions, and others have syntaxial quartz overgrowths or strained extinction. ?Potassium feldspar with syntaxial overgrowths and rounded, potassium feldspar, which has been thinned during the manufacture of the slide and is surrounded by small bubbles, is rare.

Polycrystalline quartz-rich rock fragments are far less common that single quartz grains. They comprise meta-sandstone/quartzite (here quartz has strained extinction); clast-supported sandstone with quartz and chert clasts; quartz cemented by cherty silica and chert. Other rare rock types include felsite, granophyre/myrmekite, foliated quartz-mica phyllite and fine-grained ?tuff.

Small, rounded, brown areas with gas bubbles, some with fine-grained, acicular crystals in a felted texture are common within the clay and visually resemble glaze.

Rare, rounded to tabular opaques have a wide size range.

Void spaces are abundant and linear, or have a similar size and shape to the larger quartz/rock and opaques clasts.

The ?glaze
The clay-?glaze/vitrified clay junction is sharp and the ‘glaze’ is zoned and complex. Brown clay passes into black clay passes into ‘glaze’ with extremely fine-grained opaques so densely packed that the ‘glaze’ is almost opaque. Rounded gas bubbles and ?heat crazed quartz is enclosed in this material and the density of the clasts is very high. Locally the opaques are slightly coarser and are equant in shape and may be magnetite.

Burslem School of Art

Macroscopical 37-9

Sherd – unavailable.

Thin section
The pot has fired to a uniform pale reddish brown (10R 5/4 on the Geological Society of America rock-color chart).

A clean clay has sparse, <<0.1mm size quartz. Larger clasts, 0.5mm in diameter, are rounded to sub-rounded and evenly distributed. Rare, fine-grained rocks and large, rounded opaques enclosing fine-grained quartz are up to 1mm in diameter.

Microscopical 37-9

The main body of the pot.
A dark clay carries fine-grained, angular quartz. Locally, pale-fired clay forms small rounded areas.

The non-plastics are fairly abundant and are rounded to sub-rounded and have a restricted size range. They mainly comprise monocrystalline quartz grains, many of these have fluid inclusions in them, and some have syntaxial quartz overgrowths or show strained extinction. Rounded potassium feldspar, which has been thinned during the manufacture of the slide and ?replaced by a pale brown, isotropic material with small gas bubbles, is rare.

Polycrystalline, quartz-rich rock fragments are far less common than single quartz grains. They comprise meta-sandstone/quartzite (here, quartz has strained extinction) and recrystallised quartz mosaics. Fine-grained ?tuff, and felsite (polycrystalline feldspar-bearing rocks) are rare.

Small, rounded, brown areas with gas bubbles, some with fine-grained, acicular crystals in a felted texture are common within the clay and visually resemble glaze.

Opaques are common, rounded to irregular in shape and have a wide size range. Some appear to be organic/plant matter, many show shrinkage rims and others have gas bubbles in them. A large, round, opaque-rich area carries abundant, fine-grained, angular quartz.

Void spaces are mainly linear in shape.

A pale brown, irregular, grog-like clast is present close to the surface of the sherd.

The ?glaze
The isotropic ?glaze is very thin, up to 0.1mm, brown and turbid. It encloses rare quartz, and gas bubbles and very fine-grained to slightly coarser grained, equant opaques.

Macroscopical 38-9

Sherd – unavailable.

Thin section
The pot has fired to a 7mm thick, dark reddish brown (10R 4/4 on the Geological Society of America rock-color chart) clay.

A clean clay carries sparse, <<0.1mm diameter quartz. Sparse, rounded to sub-angular clasts are up to 0.3mm in diameter and are unevenly distributed; opaques are up to 1.5mm in size.

A 0.3 to 1.0mm thick black (N1) rim is ?overfired clay.

The sherd is unglazed.

Microscopical 38-9

The main body of the pot

A dark, fairly clean clay carries fine-grained, angular quartz and very rare muscovite laths and altered plagioclase. On a small scale the clay is inhomogeneous with areas of slightly siltier material.

The non-plastics are fairly abundant and are rounded to sub-rounded and have a restricted size range. They mainly comprise monocrystalline quartz grains; many of these have fluid inclusions in them and show strained extinction. Rare, rounded potassium feldspar has been thinned during the manufacture of the slide and is now surrounded by a clear, isotropic material enclosing small gas bubbles.

Polycrystalline quartz-rich rock fragments are less common that single quartz grains. They comprise meta-sandstone/quartzite, stretched/flattened quartz (much of the quartz shows strained extinction); clast-supported sandstone with quartz and chert clasts; chert and recrystallised quartz mosaics. A single quartz-potassium feldspar felsite clast is present.

Small, rounded, brown areas with gas bubbles, some with fine-grained, acicular crystals in a felted texture are present within the clay and visually resemble glaze.

Opaques are common, rounded to irregular in shape and have a wide size range; many show shrinkage rims. Some opaque areas close to the rim of the sherd carry abundant gas bubbles.

Pale brown, irregular-shaped grog-like, fine-grained mudstone clasts are present.

Macroscopical 39-9

Sherd – unavailable.

Thin section
The pot has fired to a dusky yellowish brown (10YR 3/2 on the Geological Society of America rock-color chart) but with a 1mm thick, dark yellow brown (10YR 4/2) rim.

A clean clay has abundant, fine-grained, <0.1mm diameter quartz. Thin, silty layers are up to <0.1mm thick. Larger, rounded rock and quartz clasts are fairly sparse, 0.2 to 0.5mm in diameter and fairly evenly distributed. A large clast is 1.5mm in length. Rare opaques up to 1.5mm in size have a wide size range and an irregular distribution.

A 0.8mm thick glaze has 2mm diameter, trapped gas bubbles in it.

Microscopical 39-9

The main body of the pot
A dark, clean clay carries fine-grained, angular quartz and very rare muscovite. On a fine scale the clay is inhomogeneous with thin, slightly siltier layers.

The non-plastics are fairly sparse and are rounded to sub-rounded and have a restricted size range. They mainly comprise monocrystalline quartz grains, some of these have syntaxial quartz overgrowths or show strained extinction.

Polycrystalline, quartz-rich rock fragments are less common than single quartz grains. They comprise meta-sandstone/quartzite, stretched quartz (in both quartz shows strained extinction), clast-supported sandstone with angular quartz clasts and recrystallised quartz mosaics. Small, fine-grained ?tuff clasts are rare.

Small, rounded, brown areas with gas bubbles, most with a felted texture comprising very thin, acicular crystals are widespread within the clay and visually resemble glaze.

Opaques are common, rounded to irregular in shape and have a wide size range; many show shrinkage rims. One large opaque appears to be very dark mudstone.

Rare void spaces are mainly linear in shape.

The glaze
The glaze is complex. A dark brown, inclusion-free glaze passes out into a thin zone full of gas bubbles and then into a pale brown glaze with abundant, fine-grained opaques and very thin, acicular, brown crystals and large gas bubbles. This, in turn, passes out into clear glaze with skeletal, cubic opaques (?magnetite) and rare, anisotropic, acicular crystals. No quartz is entrapped in the clay.

Nuneaton Chilvers Coton

Macroscopical 46-11

Sherd – unavailable.

Thin section
The pot has fired to a brownish grey (5YR 4/1 on the Geological Society of America rock-color chart) paste with a 1mm thick, moderate reddish brown (10R 5/6) rim. Pale yellow-fired areas are 0.5–1.5mm in size and the main paste has been unevenly fired to red and green colours on a micro-scale.

The clay carries abundant, <<0.1mm diameter quartz grains. Single grains are 0.5mm in size and are quite evenly distributed. Rare opaques are up to 0.5mm in diameter.

The pot has a darker rim but is unglazed.

Microscopical 46-11

The main body of the pot
A dark clay carries fine-grained quartz and rare, pale brown phyllosilicates together with larger, rounded to sub-angular, non-plastics that exhibit a tight size range. Locally thin, paler fired siltier layers occur.

The non-plastics comprise monocrystalline quartz grains many with straight extinction, plus minor amounts of rounded potassium feldspar including microcline, and rare, unaltered and altered plagioclase.

Polylithic rock fragments are at least as abundant as single grains. Most comprise polycrystalline quartz that includes meta-sandstone/quartzite (showing strained extinction); arkose with quartz, potassium feldspar and microcline; sandstone with quartz-metasandstone-chert clasts; litharenite and fine-grained quartz mosaics. Fine-grained polycrystalline feldspathic rocks, very fine-grained meta-sediments (some cut by quartz veinlets), phyllite (fine-grained foliated quartz-biotite) and very fine-grained ?tuff are present.

Rounded, opaque matter is widespread and shows ?shrinkage cracks or gas bubbles or appears to be burned out plant matter (wood).

Voids in the clay are linear and lie along the fabric of the sherd.

Macroscopical 48-11

Sherd – unavailable.

Thin section
The pot has fired from a greyish orange to a pale yellowish brown (10YR 7/4 to 10YR 6/2 on the Geological Society of America rock-color chart). A 1.5mm thick medium light grey (N6) rim is present.

A clean clay has <<0.1mm diameter quartz. Evenly distributed, larger, rounded to angular grains are 0.2–0.5mm in diameter and have a restricted size range. Polylithic, fine-grained rock clasts, up to 0.5mm in size, are present and include a 1mm long litharenite. Limonite-rich areas are 0.2–1mm in size.

The sherd is unglazed.

Microscopical 48-11

The main body of the pot.
A dark clay carries fine-grained quartz and rare, long, pale-coloured phyllosilicates (?chlorite) together with larger, rounded to sub-angular, non-plastics that exhibit a fairly wide size range.

The non-plastics comprise monocrystalline quartz grains, many showing straight extinction and/or fluid inclusions and some having ?syntaxial quartz overgrowths Quartz is accompanied by rare, potassium feldspar.

Rock fragments are as abundant as single grains and the majority are fine-grained metasediments/metamorphics. They vary in lithology with polycrystalline quartz clasts that includes meta-sandstone/quartzite (showing strained extinction); coarse-grained, clast-supported sandstone; litharenite with quartz-sandstone-chert-feldspar-sedimentary clasts; quartz-feldspar arkose; chert and fine-grained quartz mosaics. Fine-grained meta-sediments include foliated quartz-biotite or quartz-muscovite phyllite; rare felsite and granophyre/ myrmekite clasts are also present.

Sparse, rounded, opaque matter shows ?shrinkage cracks.

Voids in the clay are linear and lie along the fabric of the sherd.

The clay on the edge of the sherd is black and has many gas bubbles in it.

Nuneaton Harefield Lane

Macroscopical 51-12

Sherd – unavailable.

Thin section
The pot has fired to a uniform pale reddish brown (10R 5/4 on the Geological Society of America rock-color chart).

A clean clay carries polylithic clasts. Sub-rounded to angular clasts, 0.3–0.5mm in diameter, are evenly distributed. Very fine-grained ?mudstone is up to 2mm long and opaque areas with gas bubbles are up to 1mm in size.

A vesicular glaze is 0.2mm thick.

Microscopical 51-12

The main body of the pot
A clean clay carries sparse, fine-grained quartz together with larger, rounded to sub-angular, non-plastics that exhibit a wide size range.

The non-plastics comprise monocrystalline quartz grains, many with patchy extinction. Quartz is accompanied by rare, rounded, potassium feldspar that has been thinned during the manufacture of the slide and is now surrounded by a colourless, isotropic material with small gas bubbles.

Polylithic rock fragments are as abundant as single grains. Most are polycrystalline quartz clasts that include meta-sandstone/quartzite (here quartz shows strained extinction); clast-supported sandstone; litharenite with quartz-fine-grained volcanics-chert-phyllite-sandstone-potassium feldspar-meta-sedimentary clasts; chert and fine-grained quartz mosaics. Fine-grained meta-sediments include phyllite (fine-grained foliated quartz-biotite), meta-mudstones; some sediments are cut by thin quartz veinlets. Polycrystalline, feldspathic felsite and potassium feldspar-biotite igneous rocks are rare.

Rounded opaque matter shows ?shrinkage cracks, but a large, irregular area has abundant gas bubbles.

Voids in the clay are linear and lie along the fabric of the sherd.

The glaze

The glaze is complex. Next to the clay a colourless, thin 'glaze' passes out into a darker brown, inclusion-free glass with abundant, very fine-grained gas bubbles, this passes out into a colourless glass with abundant, fine-grained opaques and acicular crystals with first order interference colours (?feldspar/mullite) and large gas bubbles. No quartz is entrapped in the glaze.

Macroscopical 53-12

Sherd – unavailable.

Thin section
The pot has fired to a 4mm thick, moderate orange red (10R 5/6 on the Geological Society of America rock-color chart) paste with a 1mm thick, black (N1) rim.

A clean clay carries fine-grained, <0.1mm diameter quartz grains. Larger, angular grains are up to 0.5mm in diameter and are quite abundant; rock clasts are 0.2–0.5mm in size and are irregularly distributed, rare opaques are 0.5 to 1.5mm long and an irregular shaped, unusual area is 1mm in size. The pot is polylithic with rock clasts approximately equal in number to single grains.

Microscopical 53-12

The main body of the pot
A clean clay carries sparse, fine-grained quartz and rare, pale brown phyllosilicate, rare, long biotite together with quite sparse, larger, rounded to angular, non-plastics that exhibit a restricted size range.

The non-plastics comprise monocrystalline quartz grains, many with patchy extinction and some have ?syntaxial quartz overgrowths. Quartz is accompanied by rare, potassium feldspar including microcline; some has been thinned and is surrounded by a colourless, isotropic material enclosing small gas bubbles.

Polylithic rock fragments are more abundant than single grains. Most are polycrystalline quartz-rich clasts and include meta-sandstone/quartzite (showing strained extinction); clast-supported sandstone; litharenite with quartz-sandstone clasts; rounded chert and fine-grained, recrystallised quartz. Fine-grained meta-sediments include phyllite (fine-grained foliated quartz-biotite). Polycrystalline feldspathic felsite, spherulitic rhyolite and a quartz-potassium feldspar igneous rock and a quartz-muscovite intergrowth are rare. A large, matrix-supported, fine-grained sandstone clast is present.

Rare, rounded, opaque matter shows ?shrinkage cracks. A large area of ?glaze with gas bubbles and quartz clasts is enclosed within a thin, opaque rim.

Voids in the clay are few in number.

The ?glaze
A very thin, pale brown glass with large gas bubbles within an opaque rim is locally present. This may be vitrified clay

Nuneaton 11 Bermuda Road (NB99)

Macroscopical 54-13

Sherd – unavailable.

Thin section
The pot has fired to a uniform olive grey (5Y 4/1 on the Geological Society of America rock-color chart).

A fine clay carries <<0.1mm diameter quartz and fine-grained, polylithic rock clasts 0.3–0.5 but up to 1.0mm in diameter. Rare and unevenly distributed opaques are 0.1–0.5mm in size.

A greyish black (N2), 2mm thick ?glaze/slag-like glass is present and carries very fine-grained <<0.1 opaques.

Microscopical 54-13

The main body of the pot
A clean clay carries fine-grained quartz and very rare zircon, together with larger, rounded to sub-angular, non-plastics that exhibit a restricted size range.

The non-plastics comprise monocrystalline quartz grains, many with patchy extinction and some with ?syntaxial quartz overgrowths. Quartz is accompanied by rare potassium feldspar that has been thinned during the manufacture of the slide and now is surrounded by a colourless, isotropic material with small gas bubbles.

Polylithic rock fragments are as abundant as single grains. Most are polycrystalline quartz clasts that include meta-sandstone/quartzite (showing strained extinction), clast-supported sandstones, chert and fine-grained recrystallised quartz. Fine-grained meta-sediments are dominated by meta-sandstone/siltstone but include rare phyllite (fine-grained foliated quartz-mica). Polycrystalline feldspathic felsite, ?spherulitic rhyolite and granophyre/myrmekite are rare.

Rare, rounded opaques enclose gas bubbles. A large area of ?glaze with gas bubbles and quartz clasts is enclosed within a thin opaque rim.

Rounded, brown, isotropic material often comprising felted, acicular crystals enclosing gas bubbles is common throughout the clay and is anthropogenic in origin.

Voids in the clay are linear and follow the fabric of the sherd.

The ?glaze/slag
A dark brown, turbid glass has skeletal to euhedral, cubic opaques intergrown with anisotropic, acicular crystals and gas bubbles all in a pale brown, isotropic glass.
The opaques are coarse-grained and have the habit of magnetite. The distribution of the glass does not suggest that it is a surface glaze but is more slag-like.

Nuneaton 16–22 Bermuda Road (NCC79)

Macroscopical 55-14

Sherd – unavailable.

Thin section
The pot has fired to a 2mm thick, light olive core (5Y 6/1 on the Geological Society of America rock-color chart) within a moderate reddish orange (10R 5/6) margin. A 1mm thick, outer rim is also a light olive (5Y 6/1).

A clean clay has rare, <<0.1mm diameter quartz. Sparse, sub-angular to angular quartz and polylithic rock clasts are up to 0.5mm in diameter. Opaques are 0.2–1.0mm in diameter.

It is unglazed but has a very thin, locally opaque rim.

Microscopical 55-14

The main body of the pot
A clean clay carries sparse, fine-grained quartz and rare mica and a single, long chlorite-muscovite lath together with larger, sub-rounded to sub-angular, non-plastics that exhibit a fairly restricted size range.

The non-plastics comprise monocrystalline quartz grains, many have patchy extinction and some have ?syntaxial quartz overgrowths. Quartz grains are accompanied by rare, plagioclase and potassium feldspar.

Polylithic rock fragments are as abundant as single grains. Most are polycrystalline quartz clasts that include meta-sandstone/quartzite (here quartz shows strained extinction), clast-supported sandstones with quartz-chert-potassium feldspar-sandstone clasts, litharenite with chert-quartz-potassium feldspar-meta-sediment clasts and fine-grained, recrystallised quartz. Fine-grained meta-sediments include rare phyllite (fine-grained, foliated quartz-mica and quartz-biotite) and kinked phyllite.

Rounded, opaque areas show shrinkage cracks, others are deep brown and may be mudstone or limonite-rich clay.

Voids in the clay are linear and follow the fabric of the sherd.

Leicester Austin Friars

Macroscopical 80-20

Sherd – unavailable.

Thin section
The pot has fired to a uniform moderate reddish orange (10R 5/6 on the Geological Society of America rock-color chart).

A clean clay has <0.1mm diameter quartz and sparse, irregularly distributed, rounded to angular clasts up to 0.5mm in diameter. The larger clasts have a restricted size range. Yellow, fine-grained rock clasts are a similar size and rock clasts are approximately equal in number to single grains. One 1mm long, reddish brown mudclast is present.

A 2mm long area comprises gas bubbles in an opaque area.

The sherd is unglazed.

Microscopical 80-20

The main body of the pot
A clean clay carries fairly sparse, angular quartz, muscovite and rare, pale brown phyllosilicates together with larger, fairly sparse, rounded to sub-angular, non-plastics that exhibit a restricted size range. The fine-grained, angular quartz is larger than in most of the Midlands purple sherds.

The non-plastics comprise monocrystalline quartz grains, many have patchy extinction and have ?syntaxial quartz overgrowths. Quartz is accompanied by rare, potassium feldspar.

Polylithic rock fragments are as abundant as single grains. Most comprise polycrystalline quartz that includes meta-sandstone/quartzite; flattened quartz (in both quartz shows strained extinction); clast-supported and matrix-supported sandstones with quartz and chert clasts; arkosic sandstone; siltstone; chert, and fine-grained recrystallised quartz.

Spherulitic quartz-feldspar granophyre and very fine-grained volcanics including feldspathic tuff are rare.

Rare, rounded, dark brown, anisotropic clay ?clasts are present and a very large, irregular, opaque area enclosing fine-grained, angular quartz appears to resemble the main clay but for its colour.

Rare voids in the clay are linear and follow the fabric of the sherd.

Macroscopical 81-20

Sherd – unavailable

Thin section

The pot has fired to a uniform dark yellow orange (10YR 7/6 on the Geological Society of America rock-color chart).

A very clean clay carries no fine-grained quartz but has sparse, larger, rounded quartz up to 1mm in diameter. Opaques are common, 0.5–1mm in diameter and may be oxidised framboidal pyrite.

The sherd is unglazed.

Microscopical 81-20

The main body of the pot.
A clean clay carries fairly sparse, angular quartz, muscovite, rare, pale brown phyllosilicates and mixed muscovite-chlorite together with larger, fairly sparse, sub-rounded to sub-angular, non-plastics that exhibit a restricted size range.

The non-plastics mainly comprise monocrystalline quartz grains, and many have fluid inclusions and strained extinction accompanied by rare, potassium feldspar.

Rock fragments are less common than single grains. They are mainly polycrystalline quartz and include meta-sandstone/quartzite (here quartz shows strained extinction), clast-supported sandstones, sandstone with a chert cement. Mudstone/red mudclasts, limonite clasts and coarse-grained ?kaolinite are present but voids in the clay are rare.

Widespread opaques are rounded or euhedral and may be oxidised pyrite.

Macroscopical 82-20

Sherd – unavailable

Thin section
The pot has fired to a uniform light brown (5YR 6/4 on the Geological Society of America rock-color chart).

A clean clay carries <<0.1mm diameter quartz. Larger grains are rounded to sub-angular, have a restricted size range of about 0.5mm diameter but are up to 2.5mm in size and are evenly distributed. Rare opaques/red mudclasts are 0.2–0.5mm in size. Large voids are up to 1.5mm in length.

Microscopical 82-20

The main body of the pot
A clean clay carries fairly sparse, rounded quartz, muscovite, rare phyllosilicate, plagioclase and zircon together with larger, fairly sparse, rounded to sub-angular, non-plastics that exhibit a restricted size range. The clasts are almost monolithic.

The non-plastics mainly comprise monocrystalline quartz grains, and some have syntaxial quartz overgrowths and strained extinction. This quartz is accompanied by rare, potassium feldspar including microcline and perthite; some feldspar has been thinned during the manufacture of the slide and is surrounded by a colourless, isotropic material enclosing small gas bubbles.

Rock fragments are far rarer than single grains. They comprise polycrystalline quartz that is dominated by meta-sandstone/quartzite (here quartz shows strained extinction) plus rarer stretched quartz, sandstone, chert, chert with radiating silica and recrystallised quartz. Polycrystalline feldspathic rocks (felsite), granophyre/myrmekite and quartz-feldspar igneous/metamorphic rock clasts are present.

Opaques are rounded to elongated and have shrinkage rims.

Voids in the clay are linear and follow the fabric of the sherd.

Macroscopical 87-21

Sherd – unavailable.

Thin section
The pot has fired to a uniform light greenish grey (5GY 8/1 on the Geological Society of America rock-color chart).

The clay is very clean. Larger, rounded, evenly distributed clasts are 0.5–0.7mm in diameter. Opaques with air bubbles are sparse but up to 0.7mm in diameter.

The sherd is unglazed.

Microscopical 87-21

The main body of the pot
A clean, isotropic clay carries sparse, small, angular quartz with larger, fairly sparse sub-rounded to sub-angular, non-plastics that exhibit a restricted size range. The clasts are almost monolithic.

The non-plastics mainly comprise monocrystalline quartz grains, and some have fluid inclusions and show strained extinction, accompanied by rare, potassium feldspar including coarse-grained microcline; some feldspar has been slightly thinned during the manufacture of the slide and is surrounded by a colourless, isotropic material.

Rock fragments are far rarer than are single grains. Most comprise polycrystalline quartz that is dominated by meta-sandstone/quartzite (showing strained extinction), but quartz-feldspar (plagioclase and potassium feldspar) arkosic sandstone and potassium feldspar-quartz ?granite are present. A single, large brown, anisotropic clay clast has an opaque rim.

Opaque areas are rounded or linear with abundant gas bubbles in them and appear to be partially infilling void spaces.

Unfilled voids in the clay are linear some are infilled with cellular filaments (plant matter?)

Macroscopical 88-21

Sherd – unavailable.

Thin section.
The pot has fired from a pale yellow brown to a greyish orange (10YR 6/2 to 10YR 8/4 on the Geological Society of America rock-color chart).

Fine-grained, <0.1mm diameter quartz is present in the fairly clean clay. Larger, rounded to sub-angular clasts are up to 0.5mm in diameter and are evenly distributed. Mudstone/laminated mudstone clasts are up to 1mm long. Sparse, rounded opaques are 0.3–0.4mm in diameter.

The sherd is unglazed.

Microscopical 88-21

The main body of the pot.
A clean, isotropic clay carries sparse, small, angular quartz, chlorite, zircon and pale brown phyllosilicates with larger, fairly sparse, rounded to sub-angular, non-plastics that exhibit a restricted size range. The clasts are almost monolithic.

The non-plastics mainly comprise monocrystalline quartz grains, some have fluid inclusions and strained extinction, and these are accompanied by rare, coarse-grained potassium feldspars some of which have been slightly thinned during the manufacture of the slide and are surrounded by a colourless, isotropic material whilst others have been totally lost.

Rock fragments are far rarer than single grains and comprise polycrystalline quartz that is dominated by meta-sandstone/quartzite (here quartz shows strained extinction). Stretched quartz, limonite-cemented sandstone and recrystallised quartz are rare. A single, large, dark, laminated mudclast within an opaque rim is present.

Small, opaque areas are rounded and have shrinkage rims.

Macroscopical 90-22

Sherd – unavailable.

Thin section
The pot has fired to a uniform pale yellowish grey (5Y 6/2 on the Geological Society of America rock-color chart) but with a 0.1mm thick, olive grey (5Y 4/2) rim.

Rare, fine-grained quartz in the clean clay is <0.1mm in diameter. Larger, rounded clasts are 0.3–0.4mm in size and unevenly distributed. Sub-rounded to sub-angular rock clasts are up to 0.3mm in size. Opaques, up to 0.5mm in diameter are common and unevenly distributed.

Microscopical 90-22

The main body of the pot
A clay carries sparse, angular quartz and pale brown phyllosilicate. Locally siltier layers carry abundant, angular quartz. Larger, sub-rounded to sub-angular, non-plastics exhibit a restricted size range. The clasts comprise monocrystalline quartz grains, some with fluid inclusions, syntaxial quartz overgrowths or strained extinction.

Rock fragments mainly comprise polycrystalline quartz dominated by meta-sandstone/quartzite (here quartz shows strained extinction). Stretched quartz, matrix-supported sandstone, chert, chert/tuff and recrystallised quartz mosaics also are present.

Rounded, brown, isotropic material enclosing gas bubbles is common throughout the clay and is anthropogenic.

Opaque areas are rounded and have shrinkage rims or are thin and linear. Unfilled voids in the clay are rare but also linear.

The ?glaze
Next to the main clay a pale ?glaze passes into a browner glaze that has abundant, fine-grained, cubic opaques (?magnetite) and trapped quartz and fine-grained rock clasts. Locally, where thicker, the brown glaze has larger, skeletal, cubic opaques and gas bubbles.

Macroscopical 92-22

Sherd – unavailable.

Thin section
The pot has fired to a uniform greyish yellow (5Y 8/4 on the Geological Society of America rock-color chart).

A clean clay has <0.1mm diameter, fine-grained quartz; larger, rounded clasts are 0.3–0.4mm in diameter and unevenly distributed. Sub-rounded to sub-angular rock clasts are up to 0.3mm in size. Rare, irregular opaques are up to 0.5mm in diameter.

Microscopical 92-22

The main body of the pot

The clay carries angular quartz and pale brown phyllosilicates and rare, longer chlorite laths. Larger, sub-rounded to sub-angular, non-plastics exhibit a restricted size range and are quite sparse. The clasts comprise monocrystalline quartz grains with fluid inclusions, rare syntaxial quartz overgrowths and strained extinction. Coarse-grained potassium feldspar has been thinned during the manufacture of the slide leaving a colourless, isotropic material with gas bubbles.

Rock fragments are similar in amounts to the single grains and are mainly polycrystalline quartz that includes meta-sandstone/quartzite (here quartz shows strained extinction), stretched quartz, fine-grained sandstone, cherts and recrystallised quartz. Rare, very fine-grained mudstone, polycrystalline feldspathic rocks and fine-grained metamorphic rocks are also present.

Rounded, brown, isotropic material enclosing gas bubbles is common throughout the clay and is anthropogenic.

Opaque areas are small, rounded and have shrinkage rims, and voids in the clay are linear in shape.

The ?glaze
A very thin, brown zoned ?glaze has an inner, pale and a darker brown, outer zone. It has abundant fine-grained opaques and encloses ?adventitious quartz and fine-grained rock clasts.

Macroscopical 93-23

Sherd – unavailable.

Thin section
The pot has fired to a 4mm thick, greyish black (N2 on the Geological Society of America rock-color chart) within a 0.5mm thick, pale reddish brown (10R 5/4) rim.

The clay is finer grained on the outer edge of the sherd and sparse, fine-grained quartz in the clay is <<0.1mm in diameter. Quartz clasts are up to 0.5mm in diameter and a very fine-grained rock is up to 1mm in size. Larger clasts are unevenly distributed. The sherd is glazed.

Microscopical 93-23

The main body of the pot
A very clean clay carries rare quartz and pale brown phyllosilicate laths. Larger, rounded to sub-angular, non-plastics exhibit a restricted size range but are quite densely distributed. The clasts comprise monocrystalline quartz grains with fluid inclusions and rare syntaxial quartz overgrowths together with lesser amounts of rounded to tabular potassium feldspar.

Polylithic rock fragments are similar in amounts to single grains. Polycrystalline quartz clasts include meta-sandstone/quartzite (here quartz shows strained extinction); fine-grained, clast-supported sandstone; sedimentary chert and recrystallised quartz. Felsite, granophyre/myrmekite, quartz-potassium feldspar 'granite', chert/rhyolite, foliated quartz-biotite phyllite, quartz-muscovite phyllite and psammite are present also.

Opaque areas are uncommon and rounded, whilst voids in the clay are linear.

The glaze
A thin, colourless, isotropic, crazed glaze with abundant, fine-grained, equant opaques (including hexagonal haematite) passes out into a glaze with coarse-grained opaques and very fine ?haematite. Locally the glaze is anisotropic

Macroscopical Ticknall AV 4266

Sherd – unavailable.

Thin section (poorly made)

The clay has fired to a dark grey (N3 on the Geological Society of America rock-color chart) core within a moderate reddish orange (10R 6/6) margin. The firing is irregular.
The clay is packed with fine-grained, << 0.1mm diameter quartz. Very rare, larger non-plastics are ?evenly distributed. Opaque rims are present about voids in the clay. The sherd is unglazed.

Microscopical Ticknall AV 4266

The main body of the pot
A very clean, isotropic clay carries rare quartz. Very sparse, larger, rounded to sub-angular, non-plastics exhibit a restricted size range. The clasts mainly comprise monocrystalline quartz grains showing strained extinction. The pot has fired unevenly and is pale and very dark fired so looks chaotic in plane-polarised light.

Polycrystalline quartz clasts include meta-sandstone/quartzite (here quartz shows strained extinction); stretched quartz; fine-grained clast-supported sandstone; sandstone with quartz and chert clasts; chert and recrystallised quartz.

Opaque areas are common, carry abundant gas bubbles and partially infill larger voids. Other voids in the clay are linear.

A dark brown ?soil with abundant, angular quartz grains coats some of the surfaces of the sherd.

Macroscopical Ticknall AV 4283

Sherd – unavailable.

Thin section
The pot has fired to a uniform moderate reddish brown (10R 5/6 on the Geological Society of America rock-color chart) but with a 1mm thick, greyish red (10R 5/2), inner rim.

The clay is quite clean with fine-grained quartz up to 0.1mm in diameter. Larger, rounded, non-plastics in the pot are fairly evenly distributed and up to 1mm in size. Opaques are rounded and up to 0.8mm in diameter. Pale-fired clay lenses are up to 2mm long.

A 6mm thick glaze is clear and is packed with rounded, quartz grains 0.5–1mm in size, clean fired clay and trapped gas bubbles.

Microscopical Ticknall AV 4283

The main body of the pot
A very dirty clay carries abundant, angular quartz and pale brown phyllosilicate laths, this is most easily seen in areas that are pale-fired. Locally, very fine clay layers are present. Larger, angular to sub-rounded, non-plastics exhibit a wide size range but are quite sparsely distributed. The clasts comprise monocrystalline quartz grains together with coarse-grained plagioclase and potassium feldspar including microcline; some potassium feldspar has been lost during slide manufacture leaving a colourless to pale brown, isotropic material with gas bubbles.

Polycrystalline quartz clasts include meta-sandstone/quartzite (here quartz shows strained extinction), stretched quartz, chert and rare psammite.

Opaque areas are rounded but locally the main cement for the fine-grained angular quartz is opaque.

Voids in the clay are rounded to linear.

A very dark brown clay carrying coarse-grained quartz, fine-grained chert, quartz with relict fine-grained carbonate, chert and a thin potsherd crumb with attached glaze ?coats the main glaze and infills large cavities within it.

The glaze

The thick glaze is zoned with a very thin rim of acicular anisotropic crystals (?feldspar/mullite) passing out into the main glaze. It carries abundant, rounded, ?adventitious monocrystalline quartz and rare, polycrystalline quartz clasts.

Select glossary of terms

‘Exotic’ fragment/clast is defined here as meaning non-quartzose, it carries no genetic/provenance meaning.