Petrological and chemical analysis of the Anglo-Saxon pottery from Scorton Quarry

Alan Vince

Introduction

Samples of most of the Anglo-Saxon pots from the Scorton Quarry cemetery have been examined using binocular microscopy, thin-section analysis and chemical analysis. This study indicates that the twenty sampled vessels were produced in at most six distinct fabrics, which probably originated in different areas. Whether the vessels arrived at Scorton through trade or embedded exchange, it is nevertheless quite clear that there was localised production of pottery rather than domestic production in each settlement. Comparative study of other collections in the north of England is at present in progress (Vince 2002) and will hopefully lead to fuller and more certain conclusions about the source and interpretation of the Scorton finds.

Methodology

After discussions with the excavators and conservator, 20 of the 24 vessels were selected for sampling (Table 1). A sherd from each of these vessels was chosen for analysis and examined at x20 magnification using a binocular microscope. The major and minor inclusions present in each sample were identified and recorded (Appendix One). About half of the sample was then submitted to the Department of Earth Sciences, University of Birmingham for thin-section preparation and the other half trimmed of any original or broken surfaces and the resulting core crushed to a fine powder and submitted to the Department of Geology, Royal Holloway College, London, where it was analysed using Inductively Coupled Plasma Spectroscopy (ICPS).

The thin-sections were polished and stained using Dickson's method (1955). This staining distinguishes dolomite from ferroan and non-ferroan calcite.

The ICPS analysis measures the following major elements, as percentage oxides: Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5 and MnO (Appendix 2a). Minor and trace elements, measured as parts per million were: Ba, Co, Cr, Cu, Li, Nb, Ni, Sc, Sr, V, Y, Zn, Zr, La, Ce, Nd, Sm, Eu, Dy and Yb (Appendix 2b). The values for Zr may be too low because of the difficulty in dissolving zircon prior to measurement.

Table 1

TSNO	RefNo	cname	Description	Subfabric	Group
V1181	181 AA	SST	SIMPLE GLOBULAR SHAPE;SOOTED AROUND RIM		sc01
V1182	250 AA	CHARN	FOOD DEPO INT		sc03
V1183	260 AA	SST	SOOTED EXT		sc01
V1184	268	SST	SOOTED EXT		sc01

V1185	275 AA	SST		+CHAFF	sc01
V1186	277 AA	ESAXX			sc03
V1187	307 AA	SST	TARRY DEPO EXT		sc01
V1188	330	SST			sc01
V1189	336 AA	CHARN	TAR DEPOSIT ON EXT;BURNT FOOD ON INT		sc02
V1190	365	MISC		VOIDS;SILTY GROUNDMASS	sc04
V1191	393 AA	CHARN	SOOTED EXT;FOOD DEPO INT		sc03
V1192	532 AA	SST			sc01
V1193	054 AA	CHARN			sc03
V1194	056 AA	SST	SOOTED EXT;FOOD DEPO INT		sc01
V1195	148 AA	SST			sc01
V1196	174 AA	CHARN			sc02
V1197	174 AR	CHARN			sc02
V1198	189 AA	ERRA	SOOTED EXT		sc01
V1199	189 AB	ERRA			sc01
V1200	195 AA	CHARN			sc03
V1201	197	SPARC			calc
V1202	200	SPARC			sc05
V1203	228 AA	SST			sc01
V1204	231 AC	SST			sc01

Petrological analysis

Given the size of the inclusions in these wares, often 2-3mm across, the thin sections could not give a full picture of the range of inclusions in the vessels. The sections are therefore most use as a guide to the character of the groundmass, which is almost impossible to classify by eye because of the small size of any inclusions, and for the identification of the main inclusion types. A full petrological study of the vessels would require larger sections, and ideally two or three samples of each vessel.

Each section was examined under plane- and crossed polarised light and a note made of the character of the groundmass and a list of the inclusions observed. The groundmass and the character of the principal inclusions were then used to divide the vessels into subfabrics.

Subfabric 1

Abundant fragments of sandstones and angular quartz sand in a groundmass of abundant fine quartz sand. The sandstones include Millstone Grit-type sandstones, with overgrown grains of quartz and feldspar with euhedral faces and kaolinite deposited in the interstice and finer-textured sandstones with a brown or red cement. Sparse rounded quartz grains, which in the hand specimen are seen to have a matt surface and varying quantities of carboniferous chert were also noted. Some samples seem to have solely Millstone Grit inclusions, some solely other sandstones and others have a mixture. The general appearance of the fabrics do not suggest that these differences are evidence of different sources but it may be that detailed analysis of sufficient vessels might be able to identify groups or batches of vessels made from the same mixture of clay and temper. Organic inclusions were noted in several sections but it is not clear whether these were evidence for deliberate chaff or dung tempering or naturally present inclusions in the parent clay. An interesting absentee, given its presence in many other samples of sandstone-tempered vessels in north Yorkshire, is basic igneous rock but in the main these samples could be paralleled closely at other sites, such as Catterick and Piercebridge.

Two samples which might deserve their own subfabric were V1198 and V1199. At x20 magnification they were seen to contain moderate quantities of dark, unidentified rounded rock fragments. In thin section, this was identified as a chert, in which numerous microfossils were visible. The remaining inclusions are, however, typical of this subfabric: finegrained sandstone fragments with a brown or red cement and abundant angular quartz sand of coarse silt/fine sand grade. The two samples come from the same grave, 189, and were clearly made from the same batch of clay.

Subfabric 2

This subfabric contains angular fragments of a biotite granite in an inclusionless groundmass. The only additional inclusions noted in thin section were organic inclusions in one of the three samples. There is no evidence from these sections for the presence of detrital grains and it seems likely that crushed or fire-cracked rocks were added to a fine-textured clay.

This method of tempering, with large angular inclusions, normally of a single rock type but sometimes two or three different types, is well-known in the north of England in the later prehistoric period alongside the use of detrital sand tempering and the use of naturally ‘self-tempered’ clays. The tradition seems to have survived into the post-Roman period and a vessel accompanying a female inhumation at Binchester has a similar fabric. The three samples come from two graves, 336 (V1189) and 174 (V1196 and V1197). The latter two samples are so similar in character that they probably either come from the same vessel or from two vessels made from the same batch of clay.

Subfabric 3

This subfabric also contains fragments of angular biotite granite but in a groundmass of fine quartz sand. Unlike subfabric 2, grains of sandstones, carboniferous chert and rounded quartz sometimes occur. Rounded voids occur in one of the samples, V1186, probably indicating the original presence of rounded limestone inclusions. However, no voids were present in the thin section.

Subfabric 4

The thin section of this subfabric was ground too thin but voids which may have contained ostracod shells, up to 0.3mm long, and a possible echinoid spine, c.0.3mm diameter, were noted. The groundmass probably contained abundant quartz of coarse silt/fine sand grade.

Romano-British calcite tempered ware/subfabric 5

Two thin sections of calcite tempered vessels were made, since calcite tempering was used in the Anglo-Saxon period at West Heslerton. One of the samples is a clear example of the Vale of Pickering, late Roman ware and has moderate rhombic voids in a glauconitic clay groundmass. Sparse subangular quartz sand is also present. The other sample contains no glauconite, the voids are not so clearly rhombic in outline and contains one fragment of fine-grained sandstone of similar character to those found in subfabrics 1 and 3. In the thin section the voids are filled with clay. This sample, therefore, is not necessarily to be identified as a Romano-British vessel and is classed here as subfabric 5.

Discussion of petrological results

Subfabric 4 is clearly quite different in character to the remaining vessels from Scorton but neither the thin section nor visual examination revealed clear evidence for its source. The presence of possible microfossils suggests that it may have contained limestone inclusions and fabrics of this character are known from other sites in the Vale of York. They probably contain Permian limestone.

Subfabrics 1 and 3 differ solely in the presence/absence of biotite granite inclusions and it seems likely that both fabrics were made from a similar (or the same) parent clay. The parent clay is likely to have been variable in texture and the groundmass has the same range of minerals present as the major inclusions. It is likely, therefore, to have been a boulder clay to which differing tempering materials, probably all detrital gravels plus, sometimes, chaff, were probably added.

Subfabric 2, however, is different in the character of the groundmass and in the nature of the inclusions, which seem to have been freshly crushed.

Chemical analysis

The chemical data was analysed using Microsoft Excel and WinBASP's version of Principal Components Analysis (PCA). The data were first examined as a single dataset and then alongside data from other sites in midland and northern England.

CHARN

All but one of the biotite granite tempered vessels sampled for chemical analysis has a similar chemical composition. The exception, V1193, has a very high Cu value (2616ppm) but also has a higher 'silica' content (ie the total unmeasured fraction) and a correspondingly lower Al_2O_3 value. It is also lower in its MgO, CaO, K_2O, Ba, Sr but higher in MnO, Co, Cu and Pb. It is likely that these results are due to either a fragment of a copper-rich ore or, perhaps an actual fragment of metal in the sample. There was no visible sign of such a fragment in the hand specimen, where the fabric looked very similar to the remaining examples in this group.

ERRA

The two samples containing abundant rounded grains of a dark fine-grained rock, believed to be a basic igneous rock have very similar chemical compositions. Given that they were found in the same grave (189) it is likely that they were produced from the same batch of potting clay. In thin section these inclusions were identified as carboniferous chert and both were assigned to subfabric 1.

MISC

The sample with abundant voids, V1190, has a chemical composition which distinguishes it from the two calcite-tempered samples (SPARC), as well as from all the other samples. The sample has the highest 'silica' content of all the Scorton Quarry samples and the lowest Al2O3, Na2O, K2O, TiO, Ba, Co, Cr, Sc, V and Zr values. By contrast, it has the highest MnO value.

SPARC

The two samples of calcite-tempered vessels, V1201 and V1202, have rather different chemical compositions. To a great extent these differences can be explained by the degree of leaching of the two samples. V1201 has a low CaO and Sr content whereas that in V1202 is much higher (although still only 2% CaO, as opposed to values between 8% and 15% found in unweathered late Roman calcite-tempered wares). It may be that the degree of leaching shown in V1201 is also responsible for depletion of other elements and there is certainly little visible difference between the fabrics of the two samples

SST

The samples tempered mainly with lower Carboniferous sandstone fragments, and quartz grains derived from this sandstone, mainly have a similar chemical composition. There are, however, two exceptions V1187 and V1194. There is little in the visual characteristics of V1187 to point to a difference in composition whereas the sandstone fragments in V1194 are finer in grain-size than the typical lower Carboniferous examples and have a haematite coating (either a cement or a post-burial deposit). Both of these samples have higher iron contents than the remainder, together with higher MgO and lower P2O5, La, Ce, Nd, Sm and Eu. The latter elements include the light Rare Earths which have an affinity for phosphate, both in resistate detrital minerals such as monazite and in post-burial phosphate enrichment.

Comparison with other sites

Three of the Scorton fabric groups are well-known in early to middle Anglo-Saxon ceramic assemblages in the north of England: CHARN, SPARC and SST. In the case of SPARC there is clear petrological evidence to show that the fabric was tempered with sparry calcite collected from the northern scarp of the chalk Wolds and that the parent clay used to produce this ware is the Speeton Clay, which outcrops extensively at the southeastern end of the Vale of Pickering, narrowing to a point near Malton, after which it is not exposed at the surface. Whether, within this area, there was a single source for the late Roman and Anglo-Saxon wares or not may not be determinable using chemical analysis, although petrological analysis does indicate the presence of distinct variations in the composition, which might be related to source.

The remaining two fabric groups, CHARN and SST, are much more extensive, so that the balance of probability must be that there are several sources for the ware. A further possibility for these two wares (certainly for the granite-tempered ware) is that the inclusions were being carried from site to site and mixed with local clays.

CHARN

The Scorton samples were compared with a series of chemical analyses of biotite granite-tempered wares from a variety of sites:

- sites south of the Humber, including Barton-upon-Humber, Flixborough, Catholme, Southam (Warks), City of London and Benson (Oxon).
- Sites north of the Humber, including West Heslerton, Sewerby, West Lilling, Elmswell and Hayton.

The sites also differ in likely date. The Catholme and Flixborough samples are likely to be mid Anglo-Saxon whereas the majority of the remainder are probably early Anglo-Saxon.

Statistical analysis using PCA showed that the samples formed a main cluster with a number of samples forming a diffuse subgroup. The subgroup consists of samples from Catholme, Flixborough, Hayton and Tallington. The latter sample is certainly of Early Anglo-Saxon date but the remainder are likely to be of mid Anglo-Saxon date. Amongst other differences, the overall quantity of 'silica' is lower in these samples, suggesting perhaps that they were less heavily tempered.

The Scorton samples plot in the centre and at one end of the main cluster. The other end of the cluster consists of samples from West Heslerton (mainly from area 12) and Elmswell. These samples too have a lower quantity of 'silica' than the norm. There is, thus, no chemical difference between the Scorton samples and the majority of biotite granite tempered wares, from sites north or south of the Humber but mainly of early Anglo-Saxon date. Interestingly, the aberrant Scorton sample, V1193, plots with the remainder in this analysis.

SPARC

The Scorton samples were compared with data from various other groups of Calcite-tempered pottery:

- A group of probably prehistoric sherds from Kexby, in the Vale of York
- Late Roman samples from West Heslerton

- Late Roman samples from West Lilling, in the Vale of York
- Anglo-Saxon samples from West Heslerton

The results were studied using Principal Components Analysis to investigate the similarity of samples and the combination of elements responsible for that similarity. When CaO and Sr were included in the analysis the samples from sites on acidic soils were clearly separated from those from West Heslerton. There is still a slight difference between these two groups when those two elements (both present in the calcite and therefore leached) were removed. V1201 plotted at the edge of the cluster, alongside samples of late Roman date from West Lilling. V1202, however, was an outlier, distinguished by the quantity of light Rare Earth elements it contains. Incidentally, the early Anglo-Saxon West Heslerton samples are less similar to the Scorton samples than are the late Roman ones. The difference between the two groups is thought to be due to the admixture, by accident or design, of quartzose sand in the Anglo-Saxon fabric. V1202 contained sparse grains of this sand whereas V1201 did not.

SST

The Scorton data were compared with chemical analyses of sandstone-tempered fabrics from a number of sites. These include:

- sites in Lincolnshire where the sandstone temper is apparently of local origin (Barton-upon-Humber and Dunholm)
- Catholme
- Various sites north of the Humber, including West Heslerton, West Lilling, Jarrow, Wallsend and Whitby.

Statistical analysis of this dataset using PCA shows that the Scorton samples are chemically similar to the majority of samples from sites in the north of England. There are slight differences between these samples and those from Catholme and clear differences between the samples from Lincolnshire and the remainder.

Of the northern English samples, those from Jarrow, Otley, Sewerby, West Heslerton and West Lilling are indistinguishable from the Scorton examples. The three samples from Whitby are clearly different, however, as is one of the Wallsend samples (probably a late/Sub Roman handmade sandy ware, rather than an Anglo-Saxon pot), and the Hayton sample.

Correlation of petrological subfabrics and chemical composition

Because only one of the two calcite tempered samples was clearly identified as a late Roman ware the other has been distinguished here as subfabric 5. Factor analysis of the data from Scorton was carried out (using the WinStat excel add-in). Five factors with eigenvalues greater than 1 were found and the scores for each sample for each factor were calculated and stored. Fig 1 shows a plot of F1 against F2.

It is clear from this plot that the two ‘calcite-tempered vessels (calc and SC05) have rather different compositions but that neither is similar to the remainder of the samples. The sample of subfabric 4 is also clearly distinguished from the remainder. Subfabrics 1, 2 and 3, however, all form one large cluster, in which the subfabric 2 vessels are distinguished by having more negative weightings for factor 1 that the other two fabrics. The similarity in chemical composition between subfabrics 1 and 3 seems to confirm the impression gained from thin section analysis, that these two fabrics are essentially the same raw materials with the addition of acid igneous rock to subfabric 3.

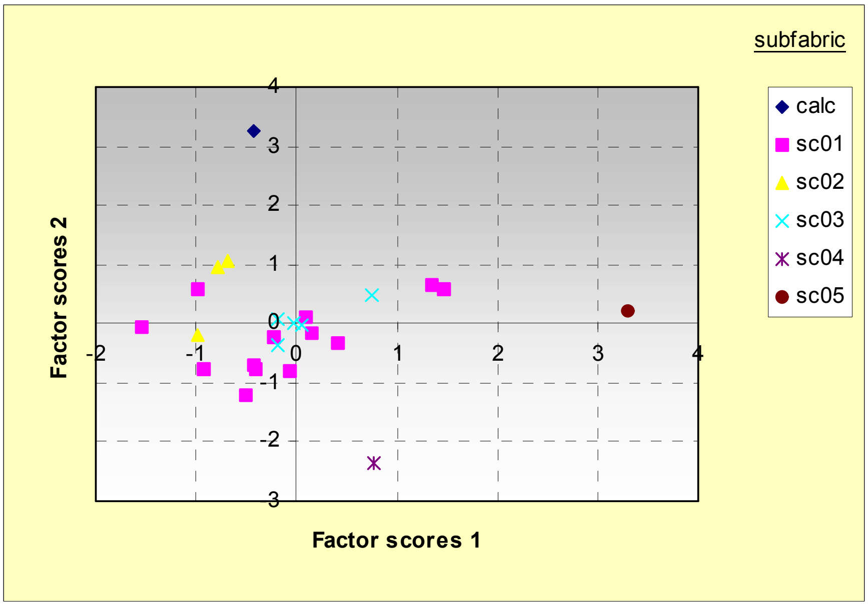

Figure 1

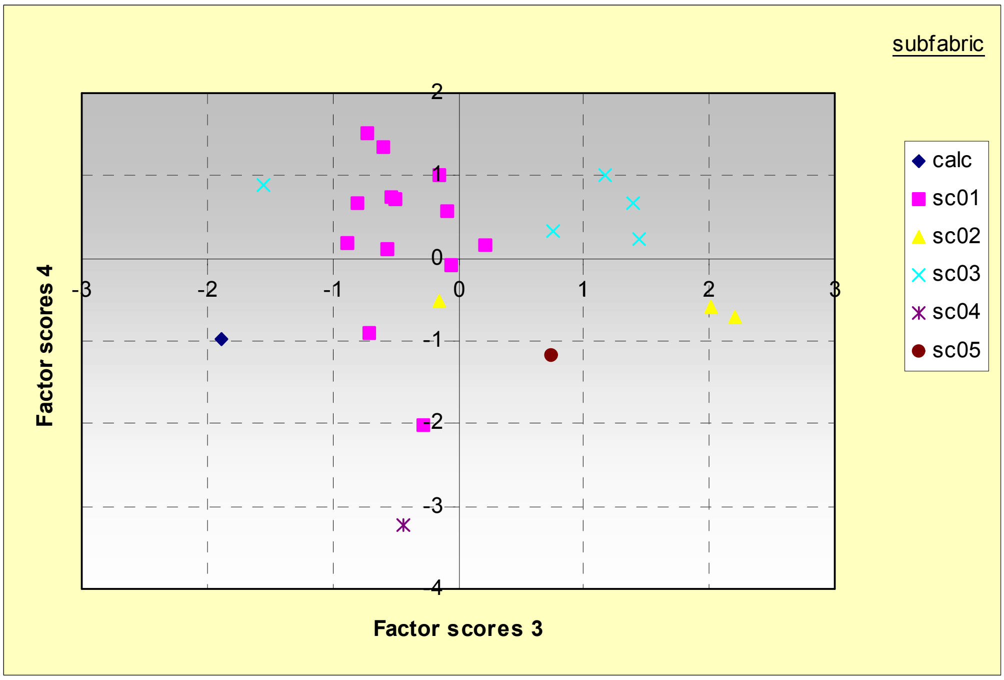

Figure 2

Fig 2 shows a plot of F3 against F4. It indicates that the F3 scores separate subfabric 1 and 3 samples. Factor 3 loadings are highest for Sr and NaO2, followed by CaO. The factor also includes a strong negative loading for Cu, and the anomalous result for this element in sample V1193 is responsible for one of the subfabric 3 samples plotting well away from the remainder. The separation is clearly reflecting the igneous rock content of both subfabrics 2 and 3.

To test the extent to which the chemical analyses were affected by burial (leaching and concretion) a factor analysis was carried out on a restricted range of elements, thought in the main to be the least mobile (Mg0, Na2O, K2O, TiO2, MnO, Li, Y, Zr and Pb). The results showed only two factors with eigenvalues over 1. A plot of these factors reveals a very similar pattern to that of the larger dataset, suggesting that in the main these results are not overly affected by burial (Fig 3).

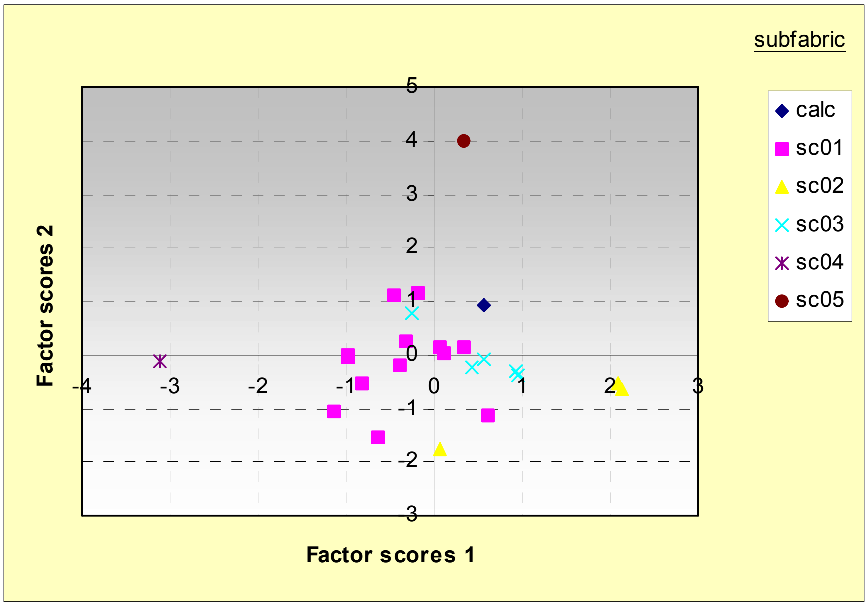

Figure 3

Following the petrological study a further comparison with other sites was undertaken. The approach was to take collections from Piercebridge, Catterick and Norton and to carry out a factor analysis of the dataset. Fig 4 shows the plot of F1/F2 for this dataset, using the original ware codes to group the results. The subfabric 4 sample from Scorton stands out against this dataset, which includes two dolomitic limestone-tempered silty wares from Piercebridge (LIMES) and two vessels tempered with rounded mixed sands from Norton (ESAXLOC). Those samples with high F1 scores are all from Piercebridge and may be of Romano-British date.

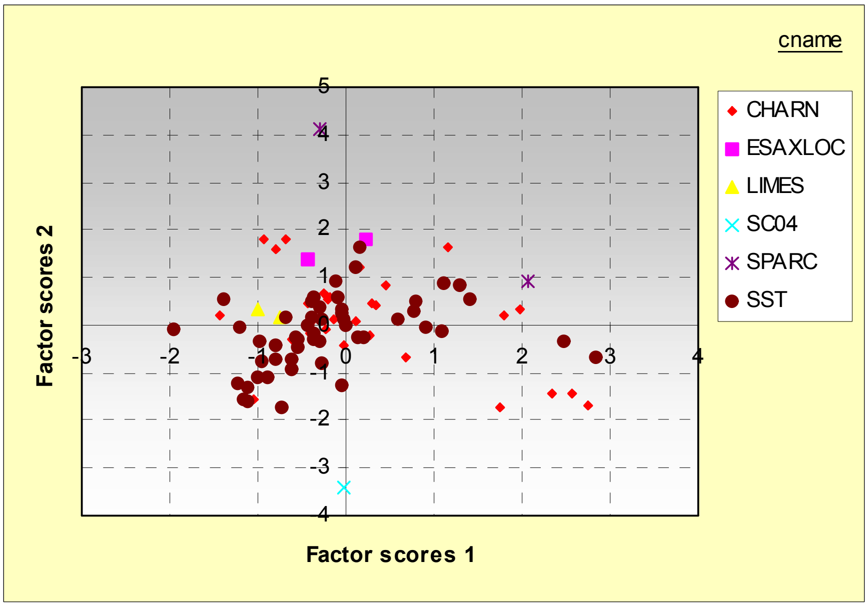

Figure 4

The plot of F3/F4 shows no discrimination between wares, but that of F1/F5 distinguished the biotite granite tempered vessels from the remainder (Fig 5).

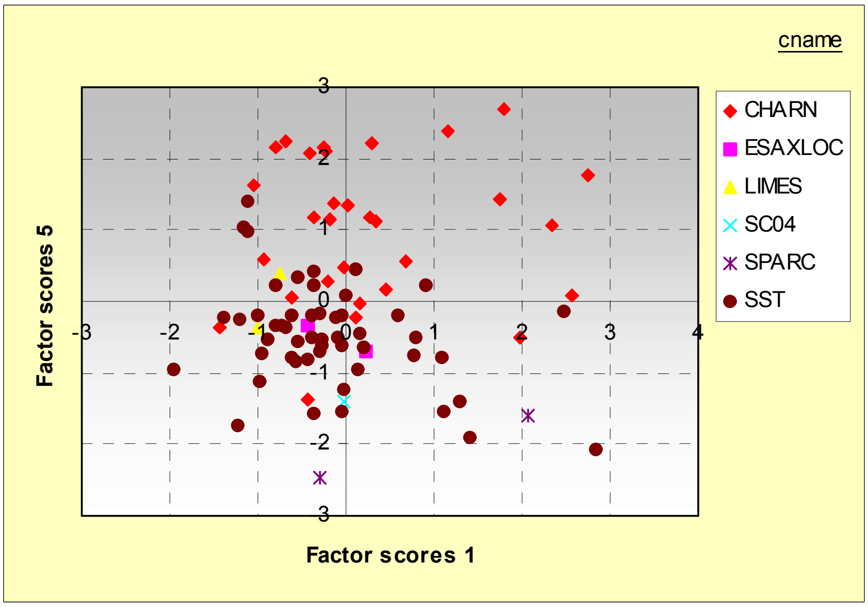

Figure 5

The analysis was repeated for the least mobile elements and this continues to indicate the unusual composition of subfabric 4 (Fig 6).

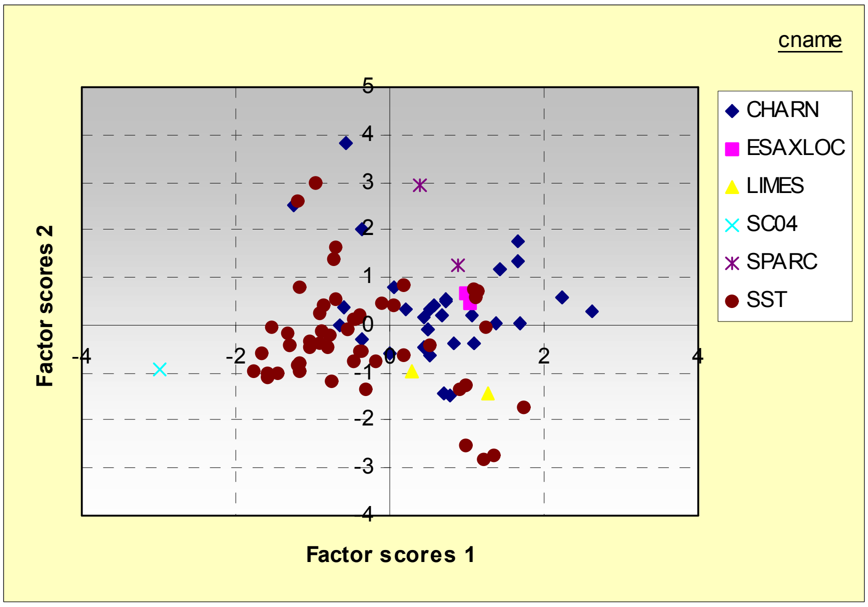

Figure 6

Finally, Zr was plotted against Al2O3 and grouped by ware and then by locality. The ware plot shows that the subfabric 4 sample, the LIMES samples from Piercebridge and the ESAXLOC samples from Norton all have outlying or peripheral values either for Zr or Al2O3 or both (Fig 7) but that the main fabric groups have similar ranges for both elements, that there is only a poor correlation between the two elements, and that the trendlines for the two groups is almost identical.

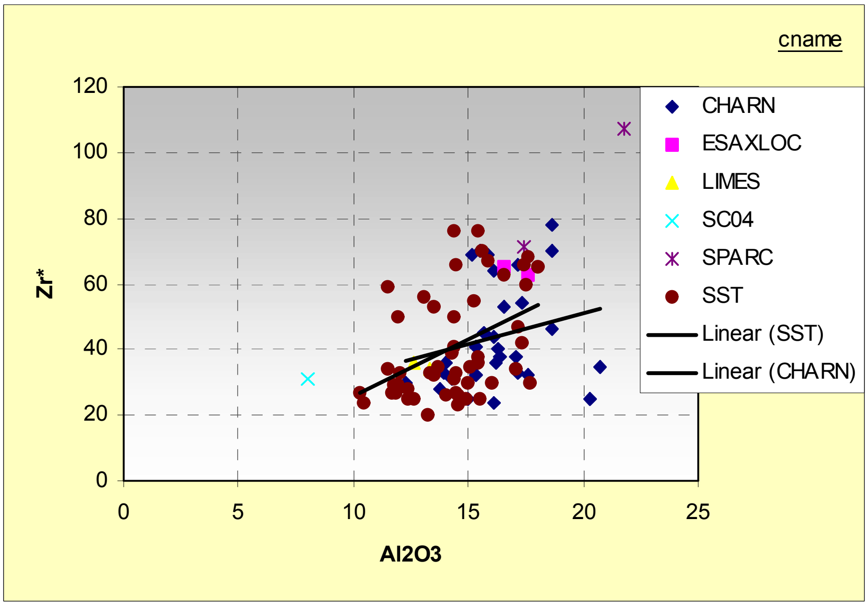

Figure 7

When the data is grouped by site a remarkable pattern is observed. There is a close correlation between Zr and Al2O3 and the ratio of Zr to Al2O3 differs for each site. Piercebridge and Catterick have almost identical ratios but Scorton has a higher ratio. A positive correlation with Al2O3 implies that the element is present in the clay fraction of the sample and perhaps therefore more susceptible to leaching or adsorption. It would, nevertheless, be worthwhile obtaining samples of soil from the sites concerned to compare their Zr content since if one cannot interpret the result as being due to post-burial alteration the implications would be that these samples came from at least two sources, one used at Piercebridge and Catterick and the other at Scorton and Norton, despite the fact that Catterick and Scorton and extremely close together.

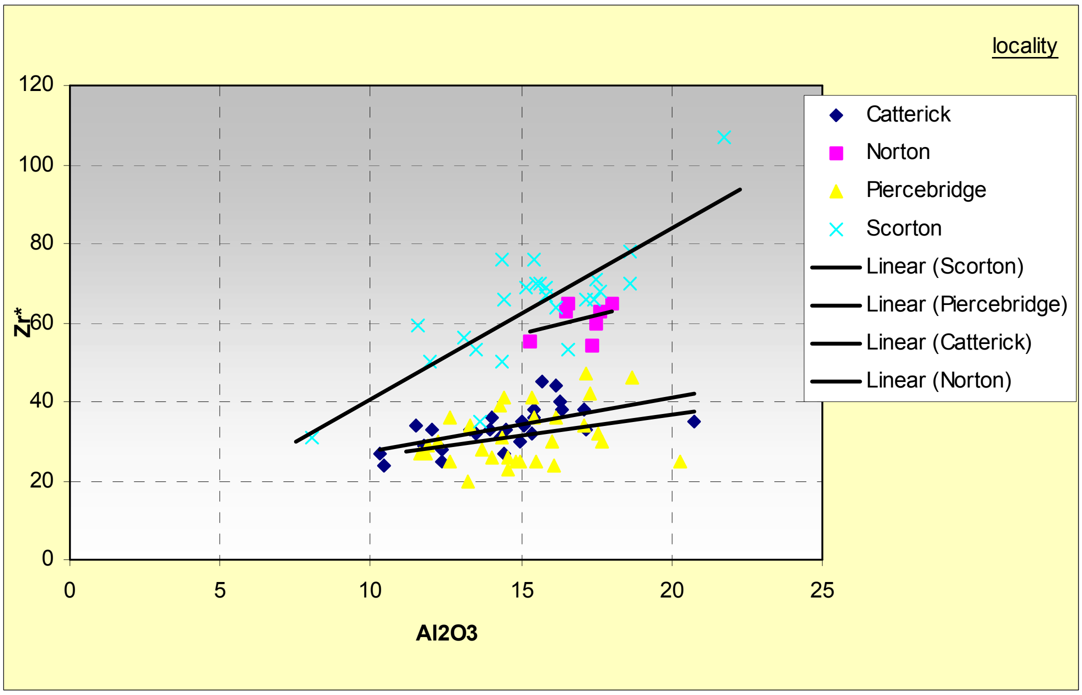

Figure 8

Conclusions

The binocular microscope and chemical analysis of the Scorton Anglo-Saxon pottery confirms that they were made from several distinct sets of raw materials. Those tempered with biotite granite (CHARN) could be divided into two subfabrics, SC02 and SC03. The former contains only igneous rock fragments and has a fine-textured groundmass. This clear distinguishes the fabric from the latter, SC03, where the range of inclusions is identical to that in SC01. The lack of rounding on any of the igneous fragments in SC03 contrasts with the character of the remaining inclusions, which are mostly clearly detrital grains. It would therefore seem that the granitic fragments in both subfabrics were deliberately added. The similarity in the range of non-igneous inclusions in SC01 and SC03 suggests that they both utilised the same parent clay and thus SC03 was probably produced ‘locally’. Chemically, SC02 is distinguishable from SC01/SC03 but this is not surprising given the difference in texture between the two groups.

A pair of samples containing chert inclusions were clearly made from the same batch of clay but the remainder of the inclusion suite is the same as the main subfabric, SC01, and the samples are chemically similar to other SC01 samples. Nevertheless, the variety of inclusion types present in this subfabric and their clear variation in relative frequency and texture does suggest that there is potential for subdividing this group into what might either be individual batches of prepared clay or random variations in a mixed parent clay.

A sample with abundant voids (MISC, SC04) which may have contained limestone has a chemical composition which distinguishes it from all the other samples. It does not have a similar chemical composition to limestone-tempered vessels from Piercebridge.

Of two samples which have been identified from their petrological characteristics as calcite tempered wares from the Vale of Pickering (SPARC), one has a similar fabric to late Roman examples (CALC) but the other does not, nor does it have the same glauconitic clay matrix. Its source is therefore uncertain.

Bibliography

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Appendix 1

TSNO	Cname	FABRIC DESCRIPTION (based on x20 binocular microscope study)
V1181	SST	Abundant SST sand:
		a) Overgrown quartz grains, no obvious cement (Lower Carboniferous/Millstone Grit) >2.0mm
		b) Subangular grains >2.0mm. Red haematite cement and coating on loose grains
		Also, sparse rounded quartz grains >1.0mm and sparse organics (not chaff)
V1182	CHARN	Moderate biotite sheaves >1.5mm. Sparse angular feldspar/granite frags. Groundmass is black (except for light brown exterior surface) and fine-textured. Some biotite laths and possible muscovite.
V1183	SST	Abundant SST sand >2.0mm. SST grains are overgrown and cemented with kaolinite. Mostly quartz with some pink feldspar. Sparse iron-rich nodules >4.0mm with concentric structure (black ore and brown crust).
V1184	SST	Fabric not easily visible in hand specimen, mainly as a result of vivianite and/or carbon deposition around grains and in laminae. Includes sparse rounded quartz grains up to 1.0mm across. Some composite grains, including biotite but finer-textured than granite. Might be sedimentary or igneous. Groundmass 'twinkles' from small overgrown quartz grains rather than micas. Therefore provisionally classified as SST
V1185	SST	Abundant organic inclusions. One seed but mainly very thin acicular voids (a grass?) Requires ID. Moderate SST grains with overgrown quartz grains and kaolinite and sparse haematite cement. Rare rounded quartz >1.0mm with matt surface (ie Permian?)
V1186	ESAXX	Not easy to see, due to consolidant. However, abundant voids, > 4-5mm, probably sparry calcite. Moderate composite grains including biotite. Finer textured than granite? SST? Abundant subangular quartz > 0.2mm
V1187	SST	Abundant SST and similar quartz >2.0mm. Overgrown quartz grains, mainly no cement but some white (kaolinite?) and haematite. No rounded quartz visible and just one rounded haematite grain. A few feldspar and composite rock frags but probably derived from SST.
V1188	SST	Abundant SST and similar quartz >2.0mm. Overgrown quartz grains, mainly no cement but some white (kaolinite?). No rounded quartz or other inclusions visible.
V1189	CHARN	Abundant fragments of biotite (euhedral sheaves, c.1.5mm across), feldspar (including grains with some rounding), composite rock (biotite, feldspar, possible quartz) >3.0mm. Fine-grained groundmass
V1190	MISC	Abundant voids. Not organic, sparry calcite or shell so presumably a limestone. Their shape does not immediately suggest

		detrital grains or ooliths. The groundmass is silty and it is not easy to see individual inclusions
V1191	CHARN	Abundant angular fragments of granite (biotite, feldspar, minor quartz) >5.0mm plus constituent grains. The groundmass 'twinkles' probably a mixture of biotite laths and overgrown quartz grains rather than feldspar, but this requires confirmation by TS.
V1192	SST	Abundant SST fragments and constituent grains >3.5mm. Overgrown quartz grains, sparse feldspar and composite rock (no biotite, probably feldspar/quartz) >2.0mm. Mainly no cement but some kaolinite and some haematite. The SST frags are subrounded and therefore from a detrital sand/gravel.
V1193	CHARN	Abundant angular fragments of granite and constituent minerals (biotite, feldspar, some quartz) >2.0mm. Iron staining on some fragments. Possibly some SST (overgrown quartz grains) >2.0mm. Groundmass contains biotite laths and overgrown quartz grains.
V1194	SST	Abundant quartz sand, including SST grains (possibly finer grain size than normal Lower Carboniferous, and with haematite cement, but this may be secondary coating) >2.0mm. Sparse rounded quartz >1.5mm. Sparse muscovite sheaves >1.0mm.
V1195	SST	Abundant SST fragments and constituent minerals >2.0mm. Overgrown quartz grains. Possibly one or two rounded quartz grains but even these may be from the SST. Groundmass 'twinkles'.
V1196	CHARN	Abundant angular granite fragments and constituent minerals (biotite sheaves, feldspar, sparse quartz) >2.00m. Groundmass is fine-textured but appears to be micaceous (cannot determine type of mica, nor whether it is all mica rather than quartz/feldspar without TS).
V1197	CHARN	Abundant angular granite fragments and constituent minerals (biotite sheaves, feldspar, sparse quartz) >2.00m. Groundmass is fine-textured but appears to be micaceous (cannot determine type of mica, nor whether it is all mica rather than quartz/feldspar without TS).
V1198	ERRA	Abundant rounded dark grains, probably basic igneous rock, varying in textures >2.0mm. Sparse SST with overgrown quartz grains >2.0mm possible haematite staining of fragments. Moderate organic inclusions. Laminated black core with silt-sized inclusions not identifiable without TS
V1199	ERRA	Abundant mixed gravel: rounded dark grains, probably basic igneous rock; subangular SST with overgrown grains; rounded medium-grained SST; rounded radiolarian chert; rounded iron-rich concretion (brown crust, black core) >2.0mm. Moderate organic inclusions. Laminated black core with silt-sized inclusions not identifiable without TS
V1200	CHARN	Abundant granitic inclusions and constituent minerals (biotite sheaves, feldspar, sparse quartz) >3.0mm. Some of these clasts are angular but others show signs of rounding. Some composite grains have fine grain size with average of 0.5mm. Fine-grained micaceous matrix, probably a mixture of biotite and muscovite.
V1201	SPARC	Abundant euhedral voids, clearly from sparry calcite >4.0mm. Sparse angular white flint >2.0mm. Sparse rounded quartz

		>0.5mm in fine-textured groundmass.
V1202	SPARC	Abundant euhedral voids, clearly from sparry calcite >4.0mm. Fine-textured groundmass.
V1203	SST	Abundant SST fragments and constituent minerals >1.0mm. Overgrown quartz grains. Mostly no cement but some white and some haematite. A single rounded quartz grain with matt surface >0.5mm.
V1204	SST	Abundant SST fragments and constituent minerals >1.0mm. Overgrown quartz grains. Mostly no cement but some white and some haematite. Fine-textured groundmass with muscovite or overgrown quartz inclusions (too small to see without TS)

Appendix 2a ICPS analysis of major elements (measured as percent oxides)

TSNO	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO
V1181	11.54	3.08	0.77	0.77	0.29	1.17	0.47	0.13	0.02
V1182	16.13	4.42	1.26	1.46	0.81	2.28	0.67	0.18	0.02
V1183	14.44	3.84	0.84	0.81	0.39	1.22	0.51	0.14	0.04
V1184	11.96	4.83	0.79	0.66	0.33	1.29	0.52	0.13	0.02
V1185	15.44	3.10	1.06	0.80	0.34	1.79	0.58	0.11	0.02
V1187	15.84	6.44	2.02	0.88	0.30	3.34	0.59	0.06	0.04
V1188	13.65	3.49	0.60	0.65	0.46	1.27	0.60	0.33	0.01
V1189	16.53	3.48	1.56	1.07	0.35	2.86	0.54	0.09	0.03
V1191	15.50	3.41	1.29	1.31	1.03	2.00	0.65	0.12	0.02
V1192	14.35	3.72	1.13	0.71	0.42	1.73	0.59	0.19	0.02
V1193	15.14	4.46	0.88	0.35	0.43	1.44	0.62	0.24	0.05
V1194	13.08	6.04	1.31	0.94	0.31	1.67	0.57	0.07	0.04
V1195	13.47	2.94	0.98	0.80	0.47	1.51	0.56	0.14	0.01
V1196	18.62	5.58	1.41	1.24	1.16	3.11	0.76	0.23	0.04
V1197	18.61	5.65	1.45	1.13	1.07	3.46	0.84	0.29	0.03
V1200	17.13	5.32	1.17	1.18	0.77	2.05	0.67	1.32	0.03
V1201	21.76	6.33	0.51	0.81	0.09	1.93	0.92	0.37	0.05
V1202	17.46	5.09	1.05	2.02	0.18	2.05	0.79	0.96	0.04
V1203	14.37	2.55	0.42	0.61	0.27	1.41	0.59	0.18	0.01
V1204	15.61	4.24	1.23	0.90	0.41	1.98	0.63	0.14	0.02

Appendix 2b Minor and trace elements (ppm)

TSNO	BA	CO	CR	CU	LI	NB	NI	SC	SR	V	Y	ZN	ZR*	LA	CE	ND	SM	EU	DY	YB
V1181	388.00	18.00	64.00	15.00	67.00	0.00	37.00	9.00	76.00	61.00	16.00	74.00	59.00	33.00	68.12	33.46	4.96	0.85	2.60	1.30
V1182	611.00	11.00	86.00	30.00	106.00	0.00	44.00	13.00	148.00	83.00	22.00	71.00	64.00	43.00	87.16	43.99	6.69	1.25	3.80	1.80
V1183	580.00	11.00	80.00	20.00	113.00	0.00	51.00	14.00	91.00	74.00	22.00	166.00	66.00	35.00	89.54	37.13	7.48	1.39	4.50	2.10
V1184	403.00	10.00	68.00	18.00	76.00	0.00	48.00	10.00	64.00	66.00	20.00	85.00	50.00	34.00	63.95	35.16	6.39	1.01	3.40	1.50
V1185	442.00	7.00	83.00	24.00	88.00	0.00	40.00	12.00	108.00	76.00	22.00	85.00	76.00	43.00	75.29	43.52	6.25	1.05	3.30	1.60
V1187	530.00	11.00	90.00	26.00	51.00	0.00	53.00	15.00	65.00	81.00	16.00	107.00	67.00	27.00	52.72	28.01	3.48	0.78	2.80	1.70
V1188	361.00	10.00	77.00	26.00	41.00	0.00	29.00	9.00	71.00	74.00	12.00	55.00	35.00	33.00	65.15	33.28	5.06	0.82	2.40	1.00
V1189	592.00	6.00	77.00	25.00	58.00	0.00	70.00	12.00	108.00	77.00	16.00	151.00	53.00	23.00	47.80	23.78	3.66	0.62	2.30	1.50
V1191	622.00	11.00	72.00	28.00	93.00	0.00	49.00	12.00	136.00	80.00	22.00	88.00	70.00	38.00	76.83	39.10	6.10	1.13	3.60	1.80
V1192	457.00	11.00	84.00	56.00	74.00	0.00	55.00	13.00	86.00	79.00	26.00	105.00	76.00	44.00	75.84	45.21	7.14	1.30	4.10	1.90
V1193	478.00	12.00	86.00	2616.00	85.00	0.00	55.00	12.00	70.00	82.00	20.00	96.00	69.00	35.00	77.63	36.57	6.17	1.04	3.90	1.80
V1194	494.00	7.00	80.00	24.00	38.00	0.00	26.00	11.00	62.00	77.00	12.00	81.00	56.00	19.00	38.96	19.83	2.78	0.52	2.10	1.30
V1195	497.00	11.00	78.00	21.00	75.00	0.00	44.00	11.00	73.00	69.00	22.00	72.00	53.00	38.00	75.26	39.20	7.33	1.26	3.70	1.60
V1196	581.00	8.00	99.00	28.00	125.00	0.00	35.00	15.00	192.00	98.00	16.00	79.00	78.00	38.00	77.59	38.07	4.51	0.85	2.50	1.80
V1197	560.00	9.00	103.00	29.00	112.00	0.00	35.00	15.00	179.00	103.00	16.00	73.00	70.00	41.00	82.94	41.27	5.68	0.95	2.90	1.80
V1200	837.00	11.00	100.00	27.00	87.00	0.00	55.00	14.00	188.00	94.00	25.00	155.00	66.00	48.00	93.11	49.35	8.14	1.47	4.50	2.10
V1201	577.00	11.00	130.00	40.00	71.00	0.00	58.00	18.00	80.00	198.00	20.00	105.00	107.00	45.00	96.09	45.68	7.14	1.19	3.60	2.20
V1202	552.00	9.00	117.00	52.00	109.00	0.00	49.00	16.00	114.00	90.00	62.00	235.00	71.00	58.00	81.80	62.42	12.76	2.59	8.40	3.70
V1203	523.00	8.00	77.00	13.00	60.00	0.00	33.00	10.00	81.00	67.00	16.00	60.00	50.00	40.00	81.22	40.51	5.73	0.90	3.10	1.30
V1204	551.00	15.00	93.00	26.00	90.00	0.00	62.00	13.00	91.00	81.00	26.00	100.00	70.00	41.00	80.02	42.30	6.88	1.26	4.00	2.00