Characterisation studies of Anglo-Saxon Pottery from the Hatton to Silk Willoughby Pipeline (HAT00)

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An assessment of the pottery found on an Anglo-Saxon settlement revealed by the Hatton-Silk Willoughby found that whilst much of the material could be paralleled with pottery fabrics found on other sites in central Lincolnshire there were a number of vessels whose fabric, as determined using a binocular microscope at x20 magnification, was unusual. A sample of these unusual types was selected for analysis using thin-sectioning and Inductively Coupled Plasma Spectroscopy (ICPS). The results of these analyses suggest that the vessels probably have a relatively local origin, since they are chemically distinguishable from sherds of similar date from sites at Brough and Dunholme.

Results

Seventeen samples were selected for study (Table 1). They were classified into six separate fgabric groups on the basis of their principal inclusions. SSTCL contains a mixed gravel which includes oolitic and fossiliferous limestones and fine-grained sandstones. The samples were subdivided into fine-textured examples (V1264 to V1266) and coarser-textured examples (V1267 to V1269). SSTMG contains a quartzose sand in which most of the grains appear to be derived from Millstone Grit. In addition, however, some of the Hatton pipeline examples contained grains of oolitic limestone (V1263 and V1258), polished quartz grains from the lower Cretaceous (V1261 and V1258) and rock and mineral fragments of igneous origin (V1261 and V1260). CHARN fabrics contain biotite and acid igneous rock fragments with some quartz and sandstone inclusions. However, V1257 also contains iron-rich rock fragments and limestone. Two samples of ESGS were studied. This fabric contains rounded polished quartz grains of lower Cretaceous origin. However, one of these samples also contains fragments of acid igneous rock and sandstone fragments (V1256) and the other contains common sandstone fragments, tentatively identified by eye as Spilsby sandstone. One sample contained a mixture of Millstone Grit and other sandstone fragments but lacked the calcareous inclusions found in SSTCL (SST, V1254). Finally, a sherd containing metamorphic rock fragments was sampled (ERRA, V1253).

Table 1

TSNO	Context	Cname	Subfabric
V1253	20313	ERRA	lmsst;unid metamorphic rock
V1254	20313	SST	mixed MG & finer sst
V1255	20350	ESGS	+ comm Sst (? Spilsby)
V1256	20313	ESGS	+ charn & sst
V1257	20350	CHARN	+ fe + limestone
V1258	20313	SSTMG	+ greensand & ooliths

TSNO	Context	Cname	Subfabric
V1259	20394	SSTMG	Mixed
V1260	20369	SSTMG	+ feldspar & biotite
V1261	20329	SSTMG	+ biotite & feldspar & greensand
V1262	20313	SSTMG	
V1263	20394	SSTMG	& ooliths
V1264	20313	SSTCL	F
V1265	20313	SSTCL	F
V1266	20394	SSTCL	F
V1267	20313	SSTCL	M + Oolite
V1268	20313	SSTCL	M
V1269	20313	SSTCL	M + oolite (? Some MG)

Petrological analysis

V1253

The thin-section contained the following inclusions over 0.1mm: Rounded quartz up to 0.5mm across; moderate euhedral quartz grains, some with kaolinite/altered feldspar adhering, up to 2.0mm across (this is a characteristic of quartz grains from the Lower Cretaceous Millstone Grit); sparse nonferroan calcite bivalve shell up to 1.0mm long; sparse rounded chert up to 1.0mm across; sparse sandstone up to 2.0mm across with brown cement and quartz grains up to 1.0mm across.

The groundmass consisted of anisotropic baked clay minerals with no visible inclusions.

There was no sign in thin-section of the erratic rock seen in the hand specimen.

V1254

The thin-section contained the following inclusions over 0.1mm across: moderate euhedral quartz grains some with kaolinite/feldspar adhering up to 1.0mm across; abundant fragments of sandstone of Millstone Grit type up to 2.0mm across; moderate angular fragments of ferroan calcite up to 0.3mm across; sparse bivalve shell up to 1.0mm across.

The groundmass consisted of anisotropic baked clay minerals with no visible inclusions.

V1255

The thin-section contained the following inclusions over 0.1mm across: abundant rounded quartz grains up to 0.5mm across; moderate rounded mudstone fragments, showing lamination up to 0.5mm across; sparse sandstone fragments up to 1.0mm across with amorphous brown cement and rounded quartz grains; sparse sandstone fragments up to 1.0mm across with ferroan calcite cement (partly leached and partly replaced by phosphate); sparse rounded calcareous grains, possibly replaced ooliths up to 1.0mm across.

The groundmass consists of a black, carbon-rich matrix containing moderate angular quartz grains c.0.1-0.2mm across.

The thin-section confirms the presence of a Cretaceous sandstone with a ferroan calcite cement, possibly the Spilsby sandstone. The rounded calcareous grains tentatively identified as replaced ooliths could also have been Chalk fragments.

V1256

The thin-section contained the following inclusions over 0.1mm across: sparse angular fragments of granite (feldspar/quartz) up to 1.0mm across; sparse sandstone fragments with a brown cement, up to 1.0mm across and containing rounded quartz grains; sparse rounded micrite, composed of a mixture of non-ferroan calcite and dolomite; moderate rounded glauconite, up to 1.0mm across; sparse angular ferroan calcite fragments up to 0.3mm across; sparse organic inclusions up to2.0mm long.

The groundmass consists of anisotropic baked clay minerals with no visible inclusions.

The thin-section confirms the visual identification of granitic inclusions and although no rounded quartz grains of lower Cretaceous type were noted the micrite and glauconite are both likely to be of Cretaceous origin.

V1257

The thin-section contained the following inclusions:

Moderate fragments of sandstone up to 2.0mm across, with grains up to 1.0mm across and an amorphous brown cement; moderate angular fragments of acid igneous rock (quartz, feldspars, biotite) up to 2.0mm across; moderate sheaves of biotite up to 2.0mm across; sparse chert or flint fragments up to 1.0mm across; sparse rounded opaque laminated clay pellets up to 2.0mm across with no visible inclusions; sparse haematite fragments up to 2.0mm across. The groundmass consists of opaque, carbon-rich baked clay minerals with angular quartz grains up to 0.2mm across.

The granitic and iron-rich inclusions seen by eye were confirmed in thin-section but no limestone was seen. The fabric is identical to that of other 'granite-tempered' vessels in the East Midlands thought to have been produced in northeast Leicestershire and to contain unweathered fragments of Mountsorrel Granodiorite.

V1258

The thin-section contained the following inclusions:

Moderate fragments of sandstone, of Millstone Grit type, up to 2.0mm across; sparse angular fragments of ferroan calcite up to 0.5mm across; sparse subangular opaque grains up to 2.0mm across; sparse subangular nonferroan micrite inclusions up to 2.0mm across.

The groundmass consists of anisotropic baked clay minerals with no visible inclusions.

The thin-section confirms the visual identification of the sandstone fragments as being probably Millstone Grit. 'Greensand' and ooliths were noted by eye but not seen in thin-section. However, the non-ferroan micrite may be chalk and the angular ferroan calcite might either be fragments of cement from a sandstone or a limestone. The inclusionless clay matrix is perhaps more indicative of a Jurassic parent clay than a Cretaceous one. In either case, this sample contains inclusion types absent from visually similar wares found on sites north of the Humber.

V1259

The thin-section contained the following inclusions:

Abundant rounded quartz grains up to 1.0mm across; moderate sandstone fragments with grains up to 0.5mm across and a brown cement; moderate sandstone fragments with grains up to 1.0mm across and a brown cement; sparse angular basic igneous rock fragments up to 1.5mm across and composed of interlocking feldspar laths up to 0.5mm long; sparse rounded chert fragments up to 0.5mm across; sparse angular biotite granite up to 2.0mm across; sparse nonferroan micrite fragments up to 1.0mm across.

The groundmass consists of carbon-rich clay with no visible inclusions.

By eye this fabric was seen to contain a mixture of sandstone types and this is confirmed in thin-section. In addition, fragments of basic and acid igneous rock are probably glacial erratics. The micrite might be chalk but the identity of the sandstones is unknown.

V1260

The thin-section contained the following inclusions:

Abundant fragments of sandstone of Millstone Grit type up to 2.0mm across; sparse rounded opaque grains up to 1.0mm across; sparse biotite sheaves up to 0.5mm across; sparse angular granite fragments up to 1.0mm across; sparse rounded quartz up to 1.0mm across.

The groundmass consists of anisotropic baked clay minerals and sparse angular quartz and muscovite.

The thin-section confirms the visual identification of this fabric as containing predominantly Millstone Grit-type sandstone together with biotite granite fragments. There are, however, no further clues to the source of the sand or clay.

V1261

The thin-section contained the following inclusions:

Moderate fragments of sandstone of Millstone Grit type, up to 2.0mm across; moderate fragments of sandstone up to 2.0mm across containing grains up to 1.0mm and an amorphous brown cement; Moderate rounded quartz grains up to 1.0mm across; sparse rounded chert fragments up to 1.0mm across; Moderate angular fragments of ferroan calcite, and sandstone with a ferroan calcite cement (containing subangular grains up to 0.5mm across); sparse angular biotite granite fragments mainly up to 1.0mm across but one 3mm long containing magnetite, biotite, quartz and feldspar.

The groundmass is anisotropic baked clay minerals containing sparse subangular quartz grains up to 0.2mm across.

The thin-section analysis confirms the visual identification of this fabric as containing predominantly Millstone Grit-type sandstone together with biotite, feldspar (ie acid igneous rock fragments) and "greensand" (in this case, probably Spilsby Sandstone).

V1262

The thin-section contained the following inclusions:

Moderate organic inclusions (some voids filled with secondary nonferroan calcite) up to 1.0mm long; moderate sandstone fragments with a brown cement up to 1.5mm across; sparse shell (?) composed of ferroan calcite, up to 1.0mm long; sparse rounded nonferroan calcite micrite up to 1.0mm across; sparse angular ferroan calcite up to 0.5mm across; sparse sandstone fragments of Millstone Grit type up to1.0mm across; sparse tabular opaque inclusions 1.0mm long by 0.3mm thick; sparse oolitic limestone with nonferroan sparry calcite cement.

The groundmass consists of anisotropic clay minerals with sparse angular quartz and sparse muscovite inclusions.

V1263

The thin-section contained the following inclusions:

Sparse rounded micrite composed of nonferroan calcite, up to 1.0mm across; sparse angular biotite granite (composite rock fragments containing feldspar, biotite and quartz) up to 2.0mm across; sparse shelly limestone containing nonferroan calcite bivalve shell in a ferroan calcite matrix, up to 1.0mm across; sparse rounded quartz up to 1.0mm across; sparse rounded ooliths up to 1.0mm across; sparse rounded micrite up to 3.0mm across; sparse rounded chert up to 0.5mm across; sparse subangular micrite pellets in a sparry ferroan calcite matrix, up to 2.0mm across.

The groundmass consists of opaque (carbon-rich) clay with abundant voids up to 0.2mm across and moderate angular quartz grains up to 0.2mm across.

V1264

The thin-section contained the following inclusions:

Abundant rounded sandstone fragments up to 1.5mm across, containing well-sorted overgrown rounded grains up to 0.3mm across and brown cement; sparse angular ferroan calcite fragments up to 0.5mm across; sparse organic inclusions up to 2.0mm long.

The groundmass consists of anisotropic baked clay and contains no visible inclusions.

V1265

The thin-section contained the following inclusions:

Abundant rounded quartz grains up to 0.5mm across; moderate sandstone fragments up to 1.0mm across, with grains up to 0.3mm across, including some kaolinite, and a brown cement; sparse angular ferroan calcite up to 0.3mm across; sparse organics up to 1.0mm long.

The groundmass consists of anisotropic baked clay minerals and sparse angular quartz grains up to 0.1mm across.

V1266

The thin-section contained the following inclusions:

Abundant rounded quartz grains up to 0.5mm across; moderate sandstone fragments up to 1.0mm across, with grains up to 0.3mm across, including some kaolinite, and a brown cement.

The groundmass consists of anisotropic baked clay minerals, mainly masked by carbon, with no visible inclusions.

V1267

The thin-section contained the following inclusions:

Moderate fragments of sandstone of Millstone Grit type, up to 3.0mm across; moderate rounded fragments of pelletal limestone up to 1.5mm across, composed of micrite pellets up to 1.0mm across in a sparry, non-ferroan calcite matrix; sparse rounded quartz grains up to 0.5mm across.

The groundmass consists of dark (ie carbon-rich), anisotropic baked clay minerals, sparse angular quartz grains up to 0.2mm across and sparse muscovite up to 0.1mm long.

V1268

The thin-section contained the following inclusions:

Moderate rounded quartz grains up to 1.5mm across; moderate pelletal limestone up to 1.5mm across; moderate organics up to 3.0mm long; moderate sandstone fragments up to 1.5mm long containing overgrown quartz grains up to 0.3mm across; moderate rounded fossiliferous limestone fragments up to

1.5mm across containing nonferroan calcite microfossils in a sparry ferroan calcite matrix; sparse shelly limestone fragments up to 1.0mm across containing nonferroan calcite bivalve shell in a sparry nonferroan calcite matrix; sparse ooliths up to 1.0mm across composed of nonferroan calcite.

The groundmass consists of anisotropic baked clay minerals and sparse ferroan calcite microfossils, including ostracods, and sparse angular quartz up to 0.1mm across.

V1269

The thin-section contained the following inclusions:

Sparse organic inclusions up to 1.0mm across; sparse sandstone fragments of Millstone Grit type up to 1.5mm across; sparse possible grog fragments up to 1.0mm across; sparse sparry nonferroan calcite up to 1.5mm across; sparse sandstone fragments up to 2.0mm across with grains up to 0.5mm across in a brown cement; sparse rounded clay pellets up to 2.0mm across with similar colour and texture to the groundmass.

The groundmass consists of anisotropic baked clay minerals and sparse ferroan microfossils and angular quartz grains up to 0.2mm across.

Discussion

These 17 samples have a wide range of inclusion types and groundmass characteristics. Their interpretation is difficult and raises several questions:

- Can we distinguish temper from naturally-occurring inclusions?
- Is the temper obtained from a single natural source or a mixture?
- What can we infer from the petrological analysis about the source of the vessels?

Ideally, we would be able to compare the inclusions found in these samples with those of clay, sand and gravel samples from the area. However, no such sampling has taken place and therefore we have to rely on geological literature and comparanda from further afield.

The site lies on the dip slope of the Jurassic ridge with middle Jurassic Lincolnshire Limestone outcropping to the west and Upper Jurassic Oxford Clay outcropping to the east. The strata in the area of the site are varied and include Snitterby Limestone, Cornbrash and the Kellaways Beds, near the base of the Oxford Clay.

The Lincolnshire Limestone includes both pelletal and oolitic facies and is the most likely source for the rocks of these types noted in samples V1262, V1263, V1267, V1268, V1269 and possibly also in V1255 (voids only) and V1256 (where it was noted after visual examination but not seen in thin-section). These fragments include definitely rounded grains and there is little doubt that they are detrital fragments, which might be expected in any calcareous gravel deposit on the dip slope.

The Snitterby Limestone is a micrite containing abundant oyster shell and with a low iron content whereas the Cornbrash also contains abundant shell but has a higher iron content. It is likely that the latter limestone is the source of the shell tempering used in mid Saxon and later ceramics in Central Lincolnshire, and in those wares the matrix of the limestone consists of sparry ferroan limestone. Bivalve shell is sparse in these samples but occurs in four samples, in two of which it is definitely present in a limestone matrix. In one case, V1264, the matrix is sparry ferroan calcite and in the other, V1268, it is sparry non-ferroan calcite. It is possible that the former is a piece of Cornbrash and the latter is Snitterby Limestone. However, no comparative material is available to the author from either formation.

The Kellaways Beds is a sandy, iron-rich clay and it is possible that some of the unidentified sandstones with brown cement, noted in eleven of the samples, are from this source. However, comparative reference material should be collected and thin-sectioned to confirm this identification.

The Jurassic clays themselves can be fossiliferous but are often free from any visible inclusions, a characteristic noted in several of these thin sections. Some outcrops are thinly bedded, which would tally with the laminated clay pellets noted in V1255 and V1257.

In total, therefore, inclusions of probable Middle to Upper Jurassic age were present in all but three of the samples. The three exceptions are: V1254, which contains bivalve shell and ferroan calcite, probably from either the Snitterby Limestone or the Cornbrash; V1258, which contains micrite and sparry ferroan calcite, which may be from the Lincolnshire Limestone or, given the identification of Cretaceous quartz grains by eye, the Spilsby Sandstone, and V1260, which contains no calcareous inclusions at all. It should be noted, however, that the only possible Jurassic inclusions in V1257 are brown-cemented sandstone and laminated clay pellets, both of which are types with a much wider potential source area.

The remaining inclusion types present are clearly non-local in origin, but may well occur in fluvio-glacial gravels. They include polished quartz grains and sandstones with a sparry ferroan calcite cement, both of which are of Lower Cretaceous age; Millstone Grit-type sandstone fragments from the Lower Carboniferous; basic igneous rocks and biotite granites. All of these inclusion types might be expected in drift deposits in central Lincolnshire (pers comm. J Aram). In the case of the sandstones there is some evidence for rounding, supporting a detrital origin, but the nature of the igneous rocks distinguishes them. They range up to larger sizes and show no signs of rounding at all. If we assume that they are glacial erratics then it would seem that they originated in till rather than in fluvio-glacial sands. The alternative interpretation is that these inclusions were added deliberately. Given the preponderance of acid igneous rock temper in Anglo-Saxon pottery throughout the Midlands this interpretation cannot be ignored. However, the presence of other more definitely erratic material makes a natural origin more likely. With this in mind, it may be significant that six of the samples have a groundmass containing coarse quartz silt, not noted in vessels made from Jurassic clays (nor Cretaceous clays, for that matter) and that all six of these sections also contain possible/probable erratic inclusions of the types described above. Taken together, these may be indications of the presence of boulder clay as an element in the potting clay (V1255, V1257, V1261, V1263, V1267 and V1269).

Table 2 Summary of inclusion types present (1) or possibly present (0.5) in thin section

TSNO	ool/pel lst	shelly lst	brown-cemented sst	laminated clay	acid igneous	basic igneous	cretaceous	millstone grit	Coarse silt
V1253			1					1	
V1254		0.5						1	
V1255	0.5		1	1			1		1
V1256	0.5		1						
V1257			1	1	1				1
V1258	0.5							1	
V1259			1		1	1			
V1260					1			1	
V1261			1		1		1	1	1
V1262	1		1					1	
V1263	1				1				1
V1264		1	1						
V1265			1						
V1266			1						
V1267	1							1	1
V1268	1	1							
V1269	1		1					1	1

Chemical analysis

Sub-samples of each vessel were cut from the sherds and the outer surfaces removed to minimise contamination from groundwater and soil. The remaining sample was crushed to a fine powder and submitted to the Department of Geology, Royal Holloway College, London where Inductively Coupled Plasma Spectroscopic analysis was carried out under the supervision of Dr N Walsh. A range of major elements were measured as percent oxides (Appendix 1a) whilst minor and trace elements were measured as parts per million (Appendix 1b).

The data were examined to identify any exceptionally high results which might be explained as the result of sampling inclusions rich in that particular element. Sample V1268, for example contains over 9% CaO, compared with just under 5% in the next highest sample (V1263). Interestingly, V1268 was not a sample in which limestone was noted in the initial survey. Remarkably, V1268 does not have the highest Sr content, which is found in V1263. It is normal to find that CaO and Sr values are closely linked. This too suggests that the V1268 result is aberrant.

To establish the similarity of each sample to others from the site the data were examined using Principal Components Analysis (PCA). This analysis shows little sign of any systematic variation in chemical composition. Variations in P2O5 content play a major role in separating the samples having a high positive PC1 and negative PC2 weighting. Li also has a high PC1 weighting, but with a high PC2 weighting. The remaining elements show signs of strong correlation. Al2O3, TiO2, Cr, V, Zr and Sc are all strongly correlated. This suggests that titanium oxides and zircon are actually present in the clay fraction of the vessels rather than as sand-sized inclusions which would be expected to show a negative correlation with aluminium. There is a second set of correlated elements: Dy, Y, Sm, Eu, Fe2O3, Ce, La, MgO and Nd. Finally, there is a looser correlation of CaO, Sr, Zn, Ba and MnO.

The Hatton pipeline chemical data were then compared with analyses of similar Anglo-Saxon wares from sites in Lincolnshire and Nottinghamshire (Brough).

Firstly, it was noted that the samples from any one site, independent of fabric, tended to be more similar to each other than to samples from other sites. This is shown in Fig 1 by comparing samples from Barton-upon-Humber, the Hatton pipeline, Brough and Dunholme. Although there is overlap between the groups of samples, the separation is quite clear, even though the samples are of wares with similar petrological characteristics (eg CHARN and SSTMG). This result can be interpreted either as showing that the parent clay used for these pots was obtained locally and different tempering materials were added to it or that the overriding factor in the chemical composition of these samples was the burial conditions. Although all of the elements measured by ICPS are to some extent mobile the degree of mobility varies with burial conditions (eg Ph values, the redox conditions and the presence or absence of organic matter are all clearly important).

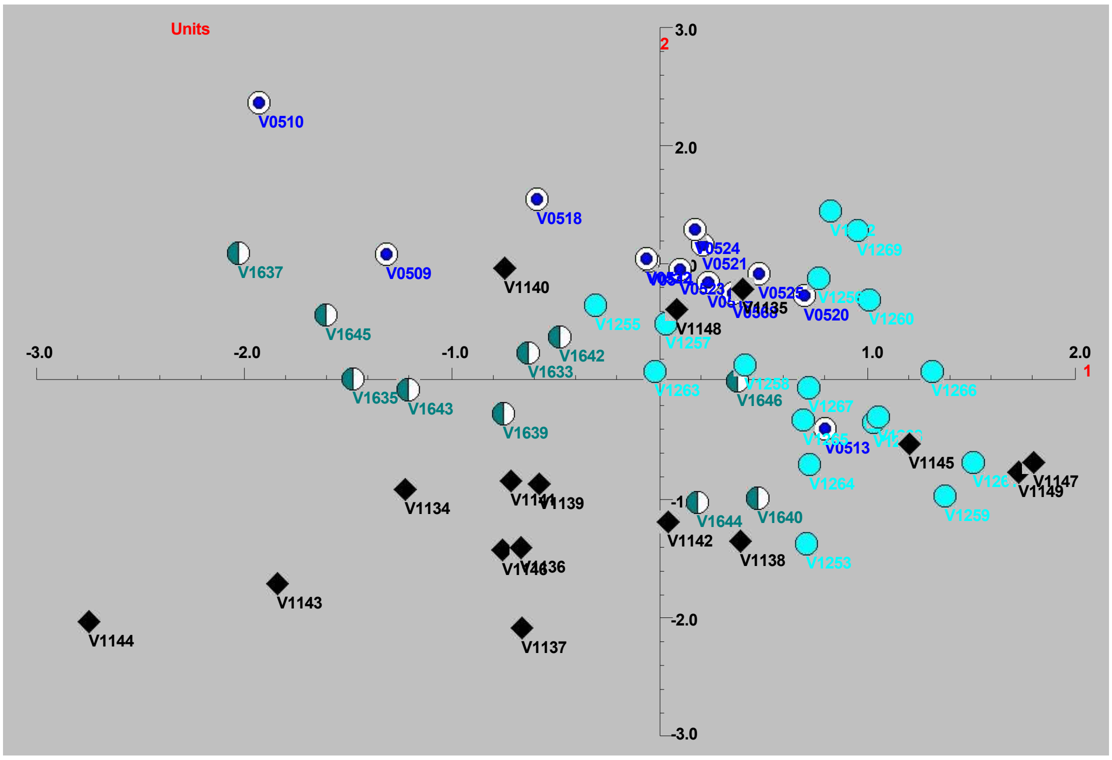

Figure 1 The Hatton samples are represented by blue filled circles.

For SSTCL there is only one comparable site, Brough. There is a clear chemical difference between the Hatton pipeline and Brough samples.

For SSTMG there are a number of comparable sites: Norton (Cleveland), Piercebridge (North Yorkshire), Brough and the City of Westminster (*Lundenwic*). A PCA study of these analyses shows that there are chemical differences between the Piercebridge, Hatton and Brough samples (only single samples were present from Norton and Westminster (Fig 1). The Hatton samples in particular are distinguished by their CaO content, which is certain to be affected by burial conditions, but also by Zr and TiO, which are likely to be original differences.

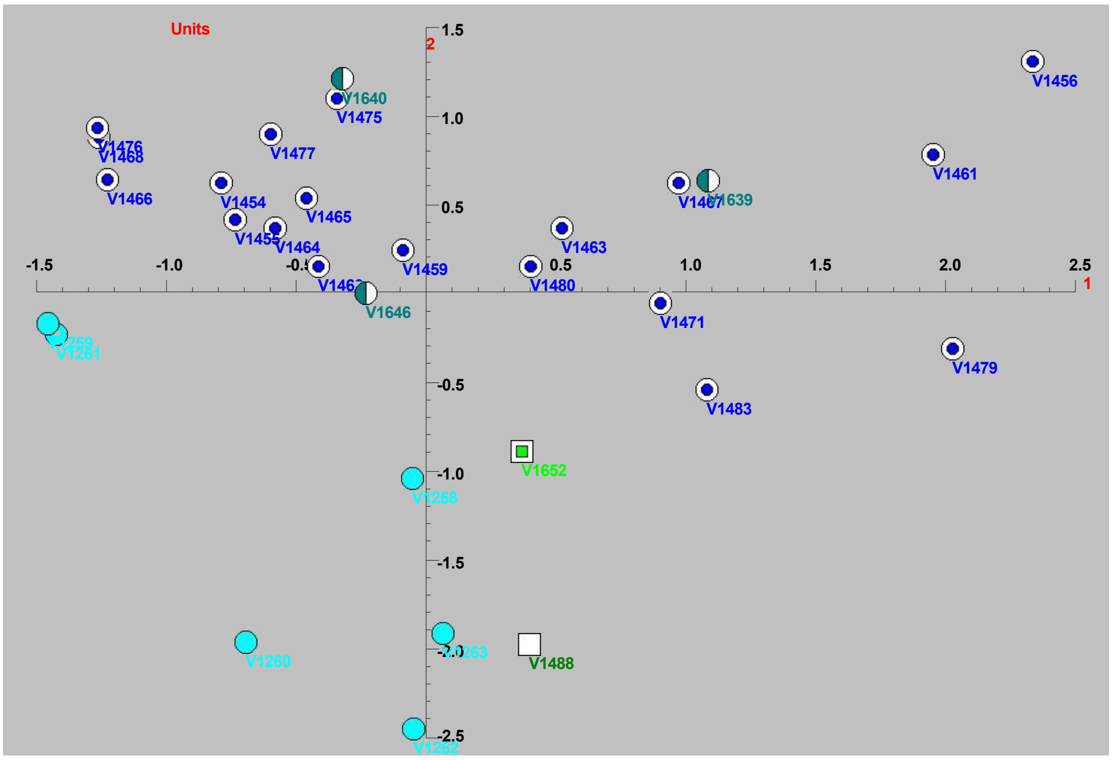

Figure 2. The Hatton samples are represented by blue filled circles

The Hatton pipeline CHARN sample was compared with a range of analyses including Catterick, Scorton Quarry, West Heslerton (all in North Yorkshire), Catholme (Staffordshire) and Brough. The Catholme samples, five of the Piercebridge samples and the Catterick samples were also chemically distinguishable but the remainder, including the West Heslerton and Hatton pipeline samples could not be separated (Fig 2).

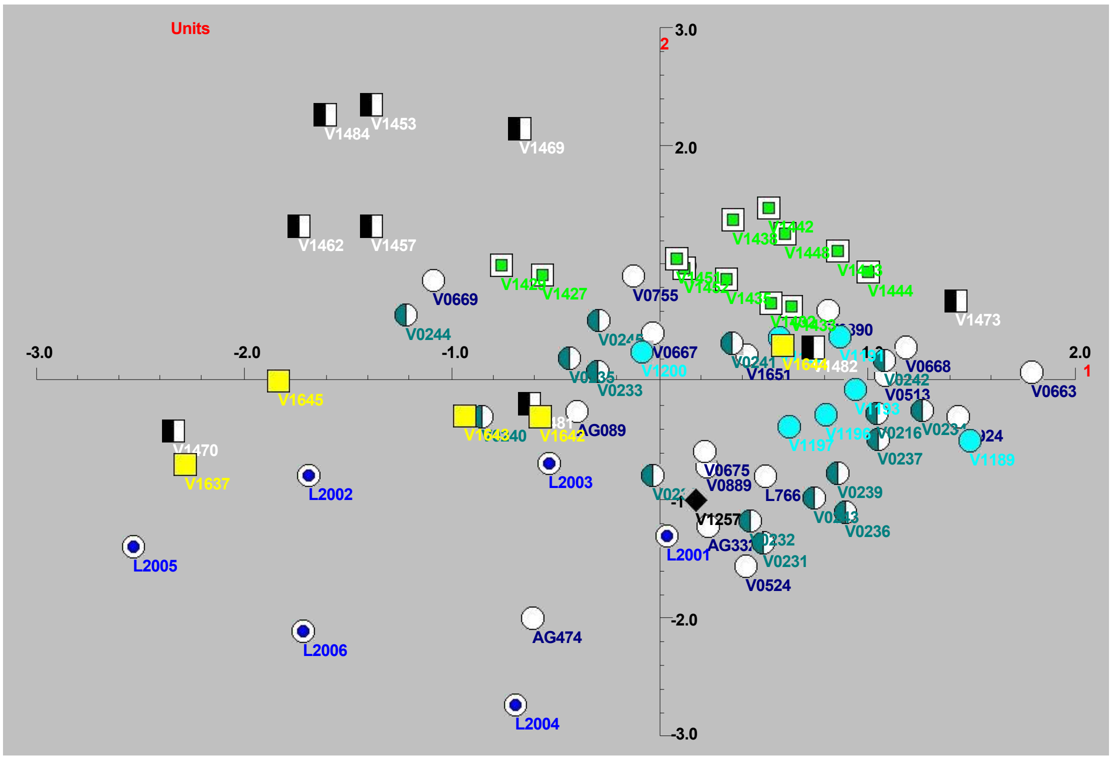

Figure 3 The Hatton sample is the black diamond.

The ERRA sample was compared with other Anglo-Saxon fabrics containing erratic inclusions. These are clearly of several different types, depending on whether the erratics are angular or rounded. However, this division does not clearly separate boulder clay from fluvio-glacial sands as rounded erratics occur in the East Yorkshire boulder clays, as a result of the complex reworking of glacial deposits. PCA readily separates the Hatton pipeline, Scorton Quarry and Easington samples and with less certainty samples from Barton upon Humber and West Heslerton. It seems likely that all these wares were produced from difference exposures of glacial clay and/or sand.

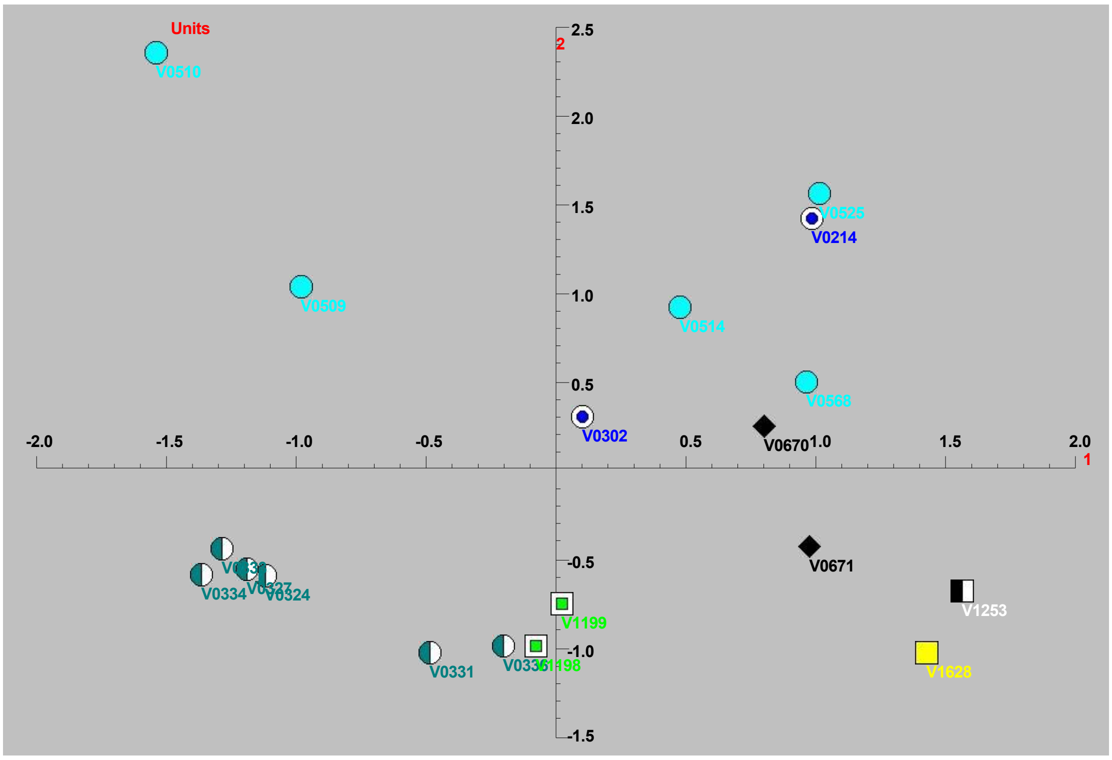

Figure 4. The Hatton sample is the half-filled square in the bottom right.

Conclusions

Taken together, the thin-section and chemical analyses of the HAT00 Anglo-Saxon pottery suggest that the vessels, despite their widely varying characteristics and the fact that in some cases these characteristics are shared by pottery present over a wide region, were locally produced. Even where, as in V1260, there is no petrological indication of a local origin the chemical composition of the sample is more closely similar to other HAT00 samples than to samples from Barton-upon-Humber, Dunholme or Brough. It has to be remembered that the samples were selected in most cases because they did not have the standard characteristics found in Anglo-Saxon pottery in Lincolnshire and elsewhere and whose very standardisation suggests some element of centralised production.

Worryingly, it was only the calcareous inclusions in these samples, many of which could not be seen and certainly could not be identified by eye, which demonstrate the local origin of the samples. Without the presence of small fragments of ferroan calcite many of these samples would have been identified visually as belonging to fabric groups with distributions stretching way to the north and south of Lincolnshire. Even more worrying is the fact that much of the remaining pottery from HAT00, which visually gave no cause for concern over its identification, also contains the same range of erratic inclusions. These wares also, would probably repay similar analyses to those carried out here.

We are left, therefore, having established that there was locally-produced pottery present at HAT00 not knowing how representative of the entire collection these samples are.

Appendix

a) Major elements measured as percent oxides

TSNO	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO
V1253	11.62	4.97	0.84	1.66	0.20	2.58	0.41	0.93	0.04
V1254	15.98	3.24	0.68	2.44	0.19	1.67	0.75	1.41	0.02
V1255	17.23	7.54	1.27	1.54	0.26	2.72	0.83	0.36	0.03
V1256	18.23	3.57	1.10	2.79	0.42	2.01	0.61	1.00	0.03
V1257	16.41	7.89	1.06	2.11	0.62	2.34	0.81	0.78	0.03
V1258	15.49	5.87	1.07	3.04	0.25	2.61	0.61	0.74	0.03
V1259	11.21	4.75	0.65	1.79	0.29	1.63	0.45	0.86	0.05
V1260	17.48	5.02	0.80	1.63	0.68	2.32	0.95	0.88	0.05
V1261	12.70	3.66	0.69	1.86	0.26	1.67	0.49	1.26	0.03
V1262	20.48	3.21	0.53	1.99	0.17	1.13	1.11	0.76	0.03
V1263	16.26	6.49	1.01	4.85	0.81	2.48	0.72	0.37	0.03
V1264	12.43	4.00	0.81	3.24	0.26	1.71	0.55	1.23	0.03
V1265	12.81	4.22	0.88	2.92	0.25	1.86	0.57	1.08	0.07
V1266	15.13	3.51	0.81	1.51	0.27	1.64	0.58	0.59	0.01
V1267	15.57	5.74	0.83	2.94	0.21	1.88	0.65	1.28	0.03
V1268	12.93	4.25	0.97	9.42	0.23	1.94	0.58	0.72	0.05
V1269	19.82	3.19	0.50	2.48	0.16	1.05	1.08	0.64	0.03

b) Minor and trace elements measured as parts per million

TSNO	BA	CO	CR	CU	LI	NI	SC	SR	V	Y	ZN	ZR*	LA	CE	ND	SM	EU	DY	YB
V1253	694	9	61	22	28	34	9	219	68	24	117	73	38	70	39.86	6.92	1.40	4.40	2.10
V1254	453	5	99	19	37	23	12	209	112	18	64	113	43	71	43.43	4.08	1.04	3.20	1.70
V1255	285	14	107	32	32	54	16	135	125	32	74	135	47	84	49.35	8.03	1.70	5.50	2.80
V1256	443	11	95	27	78	57	17	183	126	21	100	123	28	45	29.61	3.92	0.91	3.50	2.30
V1257	448	15	101	38	42	47	15	208	112	24	96	110	43	80	44.46	7.16	1.47	4.30	2.30
V1258	694	10	103	23	68	50	14	171	98	23	87	80	43	72	44.18	5.47	1.33	4.00	2.00
V1259	275	15	64	26	23	45	9	178	73	18	79	68	28	50	29.42	3.63	1.02	3.30	1.50
V1260	609	8	107	26	38	23	14	214	138	14	82	115	40	65	39.95	2.99	0.90	2.50	1.60
V1261	504	11	71	24	45	32	11	151	83	15	66	85	28	51	29.14	2.87	0.91	3.00	1.50
V1262	265	11	121	27	114	47	16	124	141	22	57	140	29	58	30.74	4.40	0.94	3.70	2.60
V1263	445	14	89	28	31	45	13	229	105	27	75	112	46	85	47.66	7.96	1.68	4.70	2.30
V1264	418	10	87	24	45	54	12	192	76	25	132	73	38	65	39.29	5.20	1.18	3.80	1.90
V1265	433	11	103	25	53	56	12	168	82	25	129	83	37	57	38.45	5.09	1.16	3.90	2.00
V1266	281	9	92	24	43	39	14	139	111	18	66	117	30	51	31.02	3.35	0.82	3.00	2.00
V1267	456	6	94	21	110	36	14	214	92	20	94	80	37	72	37.98	5.13	1.24	3.40	2.00
V1268	380	7	101	29	50	48	12	188	81	20	104	74	32	56	32.90	3.68	0.96	3.00	1.70
V1269	263	11	121	26	110	46	15	112	138	19	57	125	30	54	31.49	4.41	1.04	3.50	2.40