Characterisation Studies of Roman and Early to Mid Anglo-Saxon Pottery from Piercebridge, County Durham

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Excavations at Piercebridge produced a large assemblage of handmade Romano-British coarseware and early Anglo-Saxon handmade wares. Some of these sherds could be assigned to a production period as a result of their typology or production and decorative techniques but others could not be differentiated. Furthermore, it was clear that deposits which produced definite early to mid Anglo-Saxon pottery also produced large quantities of residual Roman material. For this reason a sample of both wares was examined by the author as part of a survey of Anglo-Saxon pottery in northern England. These samples were investigated using thin section and chemical analysis (Inductively-Coupled Plasma Spectroscopy) with the intention of determining:

a) whether systematic differences in fabric could be used to date handmade coarsewares.

b) Whether the same sources of clay and temper were used in both periods.

The samples are listed in Appendix 1 and the chemical data are listed in Appendices 3 (major elements, measured as percent oxides) and 4 (minor elements measured in parts per million).

In 2006, a series of thin sections prepared by students of Anne Woods at the University of Leicester were located and these have been incorporated into the previous study, resulting in this paper (Appendix 2).

Prehistoric and Romano-British 'native' wares

Erratic-tempered ware

Nineteen vessels were tempered primarily with angular fragments of basic igneous rock. Binocular microscope study suggests that some of the edges on these grains are slightly rounded and there are no triangular-sectioned chips such as one might expect if the material had been crushed by the potters.

Such wares have been found in late Bronze Age and pre-Roman Iron Age contexts over much of northern Britain and have been studied in detail by Wardle (REF), Lapuente (1992), the British Museum Department of Scientific Research and others (2004).

In these studies it has been noted that the identity of the basic igneous rock inclusions is consistent with their origin in the Whin Sill and similar sills and dykes cutting through the carboniferous rocks of the northeast and with the Derbyshire Traps of the Peak District.

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http://www.avac.uklinux.net/potcat/pdfs/avac2006132.pdf

Fragments of quartz dolerite are indeed present in boulder clays along the east Yorkshire coast, but never in similar quantities to those seem in these vessels and always in association with other rock types typical of the terrain of the areas from which the clays were derived.

In the case of Iron Age wares from the Vale of Pickering, it was noted that any one sample would be likely to contain basic igneous rocks of one or two lithologies only, and that these included types which would not naturally occur together in such quantities. The interpretation of this seems to be that the angular igneous rock fragments have been selected from local boulder clays and crushed, and that this selection only involved a few erratics for each pot.

In one case, #15, the vessel contained a mixture of basic igneous and acid igneous rock fragments. Other inclusions are present in these 19 vessels, but only as sparse fragments which may have been present in the clay as dug, or accidentally added alongside the igneous rock fragments. These include subangular red iron-rich nodules (#5, #84), muscovite laths (#5, #71, #84), biotite (#6), fine-grained white sandstone (#72), coarse-grained sandstone of Millstone Grit type (#13, #71) and rare, heavily wind-ablated, rounded quartz grains (#15, #72, #74, #75). The groundmass sometimes contains abundant silt-sized quartz grains. In the absence of the igneous rocks, therefore, these vessels can be said probably to have originated in an area containing detrital grains derived from Carboniferous and Permian strata, which would include much of the northeast of England.

Samples of three of these vessels were thin-sectioned (Catalogue Nos. 5, 13, and 75).

Nos 5 and 75 have very similar characteristics. The thin sections contains several angular fragments of an unidentified basic igneous rock, all of the same lithology. Those in No.75 have a slightly finer grain size than those in No.5. The fragments range from c.0.3mm to 3.0mm across. Sparse well-rounded quartz grains up to c.1.0 mm across, sparse rounded opaque grains up to 1.0mm across and sparse carbonised organic inclusions up to 0.5mm long are the only other large inclusions. The groundmass consists of abundant angular quartz and sparse muscovite laths up to 0.2mm long in a fine-textured groundmass of baked clay minerals. In much of the section this is black due to unburnt carbon but at the oxidized margins this clay appears to have a light brown colour.

The groundmass is consistent with a glacial lacustrine deposit derived from Coal Measure mudstones and sandstones. The organic inclusions were probably present in the parent clay and the basic igneous rock in this case shows no sign of rounding at all and was probably therefore crushed/fired cracked and deliberated added to the fabric. It is not clear whether the rounded quartz was deliberately added, but is probably of Permian origin.

13. Fragments of basic igneous rock and coarse-grained sandstone were noted in the hand specimen at x20 magnification but are not present in the thin section [Nick. I wonder whether this TS is correctly identified. Short of comparing it with the sherd in Barnard Castle I don’t know what we can do though].

The thin section, by contrast, contains several carbonised organic inclusions and voids where such inclusions were probably once presence. They range up to c.1.0mm long. The remainder of the inclusions consist of abundant quartz sand, with grains ranging up to 0.5mm across with rare inclusions of angular chert and fine-grained sandstone. The larger grains are well-rounded and highly spherical and the smaller grains, which range from less than 0.1mm upwards are angular and subangular. The groundmass is mostly opaque but the thin outer margin is oxidized and can be seen to contain rounded dark brown/opaque grains up to 0.1mm across.

The organic inclusions in this section appear to have been deliberately added, in contrast to No.5, and the remaining inclusions – chert fragments, rounded quartz and fine-grained sandstones - are typical of sands derived from the weathering of Triassic sandstones although the rounded quartz grains might be of Permian origin. Triassic sandstones, the Sherwood Sandstone, outcrop to the south and east of the Piercebridge area. The silty character of the groundmass suggests a possible alluvial or lacustrine origin for the clay.

An example of this fabric was found in the fill of the villa well, No.14.

14. The thin section contains moderate fragments of angular basic igneous rock and a granite. The rock fragments range from c.0.3mm to 3.5mm and there is some slight rounding of the corners of the fragments. A single well-rounded spherical quartz grain was present, 0.5mm across, together with sparse subangular quartz up to 0.5mm and sparse dark brown clay/iron oolitic concretions up to 1.0mm across. The groundmass consists of abundant angular quartz, ranging from les than 0.1mm to c.0.3mm and moderate muscovite laths up to 0.2mm long.

By contrast with Nos. 5 and 75, the large rock inclusions are of more than one lithology and show some signs of weathering. They are therefore possibly from a coarse sand or gravel containing mainly basic and acid igneous rock fragments as opposed to the deliberately crushed/shattered grains found in Nos. 5 and 75. The groundmass, however, is very similar to those two samples.

Handmade Romano-British ware

The most common Romano-British 'native' ware contains only sparse rock fragments in a groundmass containing abundant quartz silt/fine sand. Six examples were thin-sectioned, Nos.3, 7, 8, 11, 12 and 64, and these show a range of characteristics, summarised below.

These thin sections have several distinct coarse inclusion suites: quartz derived from coarse-grained sandstone (Nos. 3, 7 and 11); quartz and feldspar derived from a coarse-grained arkose (No. 12); rocks and minerals derived from a biotite granite (No.8) and a mixed sand composed of rounded quartz of Permo-Triassic origin, mudstone of probable Coal Measures origin and limestone and marl of Permian origin (No.64). None of the inclusions appear to have been artificially prepared by crushing or cracking and probably either come from coarse

sands or gravels or were natural inclusions in boulder clay. The groundmasses of these six fabrics vary in texture from almost silt-free clay to coarse silt/fine sandy clays. All, however, share a fine-textured, laminated clay matrix with dark brown clay/iron pellets. This fine textured groundmass is typical of clays derived from weathered Coal Measures mudstones. All could have been made from boulder clays or glacial lake clays in the Piercebridge area, but the differences in groundmass texture and coarse inclusion petrology suggest that the raw materials were collected from different clay exposures. Whether, these exposures were in a single area, utilised by a single group of potters, or separated by miles or tens of miles, is unknowable without a detailed survey of the sands and gravels of the Piercebridge area.

Coarse Overgrown Quartz Grains, Feldspar and Coarse-grained Sandstone

No.3. Abundant coarse angular (overgrown) quartz grains c.1.0-1.5mm across, probably derived from Millstone Grit or similar sandstone. Also rounded dark brown clay/iron pellets up to 1.0mm across and organic inclusions rounded, up to 0.5mm across. The groundmass consists of dark brown burnt clay minerals, dark brown amorphous inclusions, angular quartz up to 0.05mm across and muscovite up to 0.2mm long.

No. 7. Moderate coarse angular quartz grains as in No.3. Also rounded dark brown oolitic clay/iron concretions up to 1.5mm across. The groundmass consists of dark brown burnt clay minerals and abundant subangular quartz ranging from less than 0.05mm across to 0.4mm across and moderate muscovite laths up to 0.2mm long.

No.11. Abundant coarse angular (overgrown) quartz grains ranging from c.0.3mm to 1.5mm across. Also present were rounded dark brown clay/iron pellets, some oolitic, up to 1.0mm across. The groundmass consists of dark brown laminated burnt clay minerals, sparse angular quartz up to 0.1mm across.

No. 12. Moderate subangular fragments of overgrown quartz and altered feldspar up to 2.0mm across and a single rounded fragment of sandstone composed of overgrown quartz and one altered feldspar grain 3.0mm across. The groundmass consists of laminated dark brown clay minerals and abundant angular quartz ranging from c.0.05mm to 0.3mm across and sparse rounded dark brown clay pellets up to 0.2mm across.

Angular Biotite Granite

No.8. Abundant subangular fragments of biotite granite ranging from c.0.5mm to 3.0mm across. The fragments have irregular outlines but the sharp corners of the grains show some rounding. The groundmass consists of laminated opaque black burnt clay minerals with abundant angular quartz grains ranging from c.0.1mm to 0.3mm across. The outer margin is oxidized and rounded dark brown clay/iron pellets up to 0.2mm across are visible.

Quartz Sand

No.64. Abundant rounded quartz grains up to 0.5mm across. Also present were sparse angular quartz grains up to 1.5mm across, sparse rounded limestone up to 3.0 mm across, sparse marl up to 1.0mm across, sparse rounded light-coloured mudstone up to 1.5mm long and a single rounded fragment of slag, 4.0mm across. The groundmass consists of dark brown burnt clay minerals and dark brown rounded clay/iron grains up to 0.2mm across.

Calcite-tempered ware

Eleven examples of calcite-tempered ware were found (including catalogue numbers 70 and 77). Such vessels were produced along the southern edge of the Vale of Pickering, utilising veins of calcite which occur within the chalk of the Yorkshire Wolds, immediately to the south. Thin-section analysis has shown that these vessels were produced using the Speeton Clay, which only outcrops within the Vale, thus excluding any other possible sources within the area of the chalk outcrop, or around its fringes.

Harrold Shelly ware (1998, 115)

A single example of a south-east midlands shell-tempered ware was found (No.143). This type can be distinguished from Lincolnshire Dales ware both by its much higher shell content and by the presence of echinoid shell fragments and punctate brachiopod shells.

Early to Mid Anglo-Saxon wares

Samples of 20 vessels of early to mid Anglo-Saxon date were sampled for thin section and ICPS analysis. The vessels are all of types which either have a form or decoration which distinguishes them from the Roman native wares. On the basis of their inclusions over 0.3mm across, they can be divided into five fabric groups but these could be subdivided on the basis of their groundmass characteristics which, as with the Roman “Native” wares, vary between almost no silt/fine sand inclusions and abundant angular quartz. Two of these fabric groups do not occur within the sampled Roman sherds (Limestone and Fine-grained sandstone). The remainder are fabrics which occur within the Roman “Native” ware samples and there is no obvious petrographic difference between the Roman and Anglo-Saxon wares.

Coarse overgrown quartz grains, feldspar and coarse-grained sandstone

Nos. 22, 34, 37, 39, 40, 41, 55, 60, 61 and 135. All of these thin sections contain moderate to abundant coarse overgrown quartz grains up to 1.0mm across and altered feldspar grains of similar size (between c.10% and c.20% of the grains are feldspars). Rounded dark brown clay/iron pellets, some oolitic, are present in most sections. The groundmass varies from having very little and abundant angular quartz silt/fine sand. Moderate rounded dark brown clay pellets less than 0.2mm across occur in most thin sections.

Angular biotite granite

Nos. 21, 27, 45, 48, 118, 138 and 142. All of these thin sections contain fragments of biotite granite up to 1.5mm across in a groundmass varying in texture from being virtually silt-free to having abundant angular quartz silt/fine sand.

Quartz sand

Nos. 32, 42 and 83. These three sections contain sparse coarse quartz and feldspar grains up to 1.0mm across, sparse rounded quartz grains ranging between c.0.2mm and 0.5mm across, and sparse dark brown clay/iron pellets, some oolitic, up to 1.5mm across in a groundmass containing abundant angular and subangular quartz. One of the sections contains definite voids from burnt-out organic inclusions.

This is probably a sparsely-tempered version of Fabric 1.

Limestone

Nos. 23 and 26. These two samples contain moderate angular fragments of limestone and sparse angular fragments of fine-grained sandstone, both ranging from c.0.3mm to 1.5mm across. The groundmass consists of optically anisotropic light brown baked clay minerals and abundant well-sorted quartz grains and sparse muscovite laths ranging from c.0.05mm to 0.15mm long.

The limestone is a grey biomicrite containing rounded quartz grains, rounded fragments of nacreous bivalve shell, coral, echinoid spines and punctate brachiopods. Dark brown clay/iron compounds occur as the filling of some fossils and as a replacement of the micrite groundmass. Several of the quartz grains are well-rounded but lack the high sphericity of Permo-Triassic grains and are closer in appearance to those found in lower Cretaceous deposits.

The sandstone consists of well-sorted overgrown quartz grains c.0.1-c.0.3mm across with both kaolinite and brown clay infilling of pores.

A single angular fragment of acid igneous rock (altered feldspar and sparse quartz) 1.0mm across was also present.

The closest source of limestone would be the Permian Magnesian Limestone which outcrops extensively in County Durham. However, chemical analysis indicates a low magnesium to calcium ratio in these two samples. Chemical analysis also indicates a higher chromium content than that found in the other samples which indicates a different source for the clay as well as the limestone. Both of these features are, however, matched by samples of limestone-tempered Anglo-Saxon vessels from West Heslerton where the limestone inclusions were thought to be from the Upper Jurassic Corallian limestone which outcrops around the north and southwest fringes of the Vale of Pickering.

Fine-grained sandstone

No.33. This sample contains a mixture of coarse inclusions: moderate fine-grained sandstone containing well-sorted overgrown quartz grains up to 1.0mm across; moderate well-rounded spherical quartz grains up to 1.0mm across; moderate subangular chert up to 1.0mm across; sparse subangular opaque grains up to 1.0mm across; sparse coarse-grained sandstone up to 1.5mm across; and sparse basic igneous rock up to 1.0mm across. The groundmass consists of opaque black burnt clay minerals and abundant angular quartz ranging from c.0.05mm to c.0.3mm across and sparse muscovite up to 0.1mm long.

The coarser inclusions in this sample come from a variety of sources but most are consistent with a local fluvio-glacial sand or gravel derived from Carboniferous and Permian rocks and erratic biotite granite, probably from the Lake District or southwest Scotland (Ixer in Vince forthcoming). The fine-grained sandstone might be of Carboniferous origin but is similar to Jurassic sandstones. Similar sandstones were noted at x20 magnification in Nos. 7, 8, 12 and 79 as well as in the limestone-tempered samples, where a Jurassic origin is quite likely.

Discussion

Thin section analysis indicates that the groundmass of most of the Roman and Anglo-Saxon pot samples analysed has similar characteristics and that the immediate source is likely to have been boulder clay or glacial/post-glacial lake deposits, to which a series of distinct sands were added. The significance of these different tempers is not known but most contain inclusion types which one would expect to find in Quaternary deposits in the Piercebridge area, given the Carboniferous and Permian strata over which the ice and south and east-wards draining rivers would have flowed.

Two Anglo-Saxon vessels (Nos. 23 and 26) with limestone temper appear to have been brought to Piercebridge, since the limestone is probably the Upper Jurassic Corallian rag whose nearest outcrop to Piercebridge is the northern tip of the Hambleton Hills, about 20 miles away and since the limestone shows no sign of weathering.

One Roman vessel (No.13 [Nick to determine whether this identification of the thin section is good enough to use]) contains quartz sand which is more similar to Triassic than Permian sands and this too may have been brought to the site from the southeast.

With these exceptions, and the prehistoric to Roman use of crushed/fire cracked basic igneous rock as temper, there is no obvious difference in the petrological characteristics of the Roman and Anglo-Saxon sherds.

Chemical analysis of these samples indicates that the Roman and Anglo-Saxon sherds have similar characteristics, if calcium and strontium and mobile elements such as phosphorous and the rare earth elements are omitted. Fig 1 shows the results of factor analysis on this restricted dataset. The samples in which fine-grained white sandstone were observed at x20 magnification are shown as triangles.

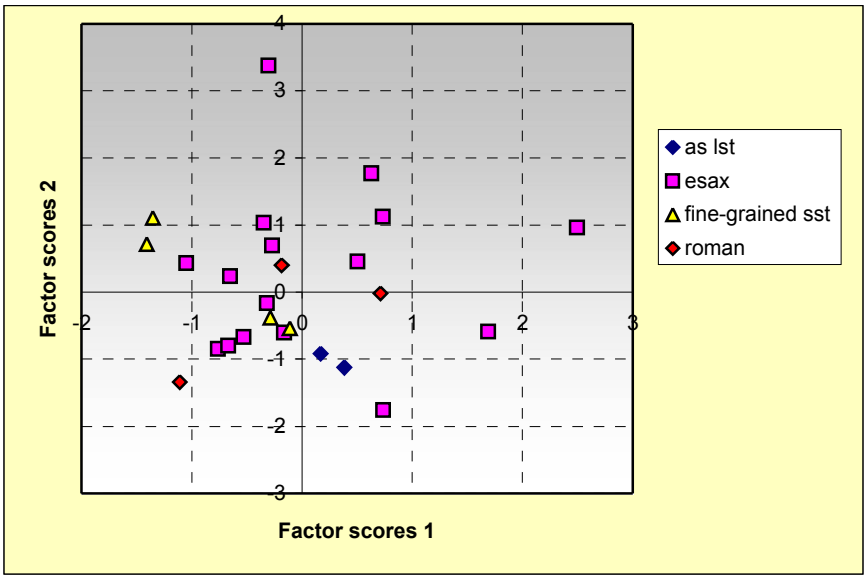

Figure 1

Fig 2 shows the same data coded by inclusion type and Fig 3 shows a plot of the two remaining factors, which indicates that the samples with granitic inclusions have higher F4 scores and lower F3 scores than the remainder, and that the samples with limestone inclusions have high F3 scores. Examination of the data indicates that this is due mainly to the higher sodium content and lower chromium content of the granitic samples. Omitting these two elements removes any sign of a difference between the sherds with sandstone and limestone inclusions but the two samples with limestone inclusions show a difference which is due mainly to their lower lithium content.

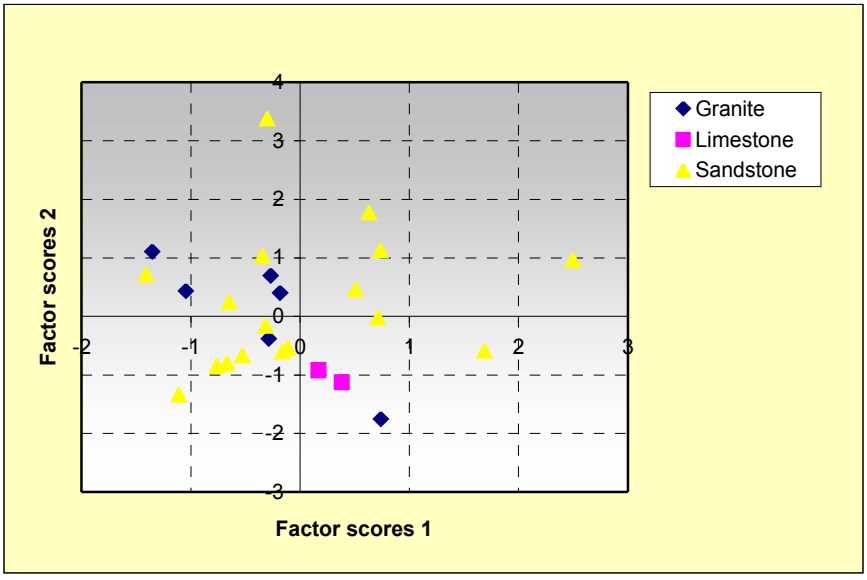

Figure 2

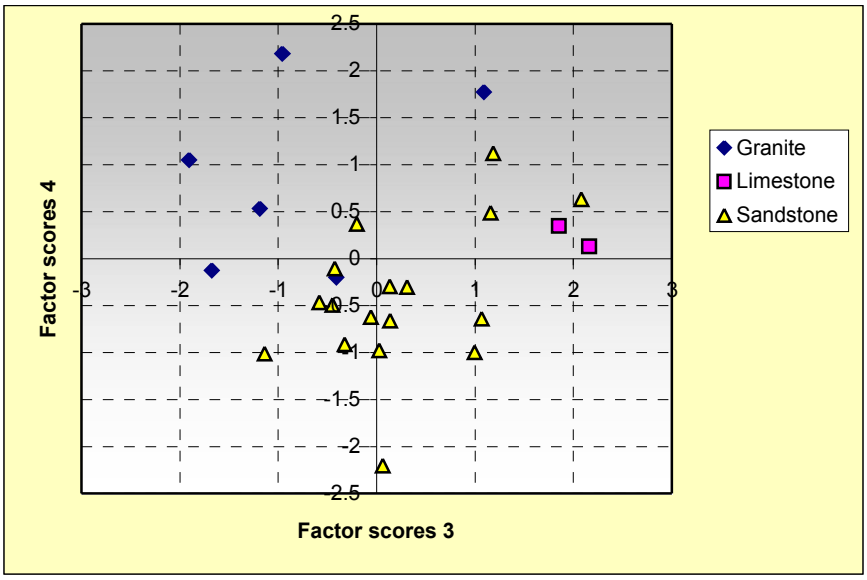

Figure 3

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Appendix 1

TSNO	Sitecode	Context	Catalogue No	cname	Form	Action	Description	subfabric
V1453	HH69	3A,W13	79	CHARN		ts;icps	VILLA;	Fabric 6, ABUNDANT SA Q >0.3MM;ROUNDED WHITE FINEGRAINED SST;M MEDIUM-GRAINED BIOTITE GRANITE (GRAINS C.1.0MM).
V1454	HH69	1,V10	3	SSTMG	JAR	ts;icps	FLAT BASE;From towards N End of subrectangular ditched enclosure; TS26	Fabric 1, SSTMG
V1455	HS78	SN,10.8	33	SSTMG		ts	SECONDARY DITCH;	Fabric 1, RQ;FLINT;ROUNDED FE
V1456	HH69	3B,V13	78	SSTMG		ts;icps	VILLA;	Fabric 7,
V1457	HH70	NEQ M10,CS	8	CHARN		ts;icps;TS(LU)	Roman ROUNDHOUSE;SF 188	Fabric 2A, ABUNDANT FINE-GRAINED Q
V1458	HH70	BW,SWQ	83	ECHAF		ts;icps	Roman ROUNDHOUSE;	Fabric 8,
V1459	HH70	L10,CS	7	SSTMG		ts;icps	Roman ROUNDHOUSE;	Fabric 6, FINEGRAINED WHITE SST
V1460	HH70	2,X14	11	SSTMG		ts;icps;TS(LU)	VILLA; TS27;NC11	Fabric 2, MUSC
V1461	HH70	2,X14	12	SSTMG	JAR	ts;icps	VILLA; FLAT BASE	Fabric 2, RQ >2.0MM;FELDSPAR;FINEGRAINED WHITE SST
V1462	HS76	AH,14.12	17	CHARN		ts	THE TEMPLE;	Fabric 2A,
V1463	HS76	(12) 5B,AR	37	SSTMG		ts;icps	MAIN DITCH;	Fabric 1,
V1464	HS76	,AS	39	SSTMG		ts;icps	MAIN DITCH;	Fabric 1,
V1465	HS76	(11) 4B,AS	40	SSTMG	GLOBULAR JAR	ts;icps	MAIN DITCH; TS24	Fabric 3,

TSNO	Sitecode	Context	Catalogue No	cname	Form	Action	Description	subfabric
V1466	HS76	(11) 4B,AS	41	SSTMG1		ts;icps	MAIN DITCH;	Fabric 1,
V1467	HS76	(15) 1B,AT	42	SSTMG		ts;icps	MAIN DITCH;	Fabric 4, HAEMATITE-C0ATED/CEMENTED QUARTZ GRAINS
V1468	HS76	(11) 5B,AS	114	SSTMG1		ts;icps	MAIN DITCH;	Fabric 2,
V1469	HS78	KG2,21.8	45	CHARN	JAR	Ts	MAIN DITCH;	Fabric 2, BIOTITE GRANITE;RQ (MATT SURFACED)
V1470	HS77	DE4,7.7	21	CHARN		ts;icps	SECONDARY DITCH;	Fabric 2,
V1471	HS77	DE4,4.7	22	SSTMG		ts;icps	SECONDARY DITCH;	Fabric 1, CHAFF
V1472	HS77	DE3,11.7	23	LIMES	JAR	ts;icps	SECONDARY DITCH;	Fabric 8, ROUNDED MICRITE;FINEGRAINED WHITE SST;SA Q >0.3MM
V1473	HS77	DQ,	48	CHARN	CARINATED JAR	ts;icps	MAIN DITCH;	Fabric 2,
V1474	HS78	9.12,LE	32	MISC		ts	SECONDARY DITCH;	Fabric 6, A SA Q >0.3;S RQ >1.0MM;MUSC >1.0
V1475	HS77	JL,	55	SSTMG		ts;icps	MAIN DITCH;	Fabric 1, MUSC;BASIC;ROUNDED FE
V1476	HS77	BG,1.3	128	SSTMG1		ts;icps	EAST OF FORT DEFENCES;	Fabric 3,
V1477	HS77	JL,14.10	135	SSTMG1	GLOBULAR JAR	ts;icps	MAIN DITCH;	Fabric 1,
V1478	HS78	KK2,26.4	26	LIMES	JAR	ts;icps	SECONDARY DITCH;	Fabric 8, SA Q >0.3MM;ROUNDED MICRITE
V1479	HS78	,AREA 505	34	SSTMG	BICONICAL JAR	ts;icps	SECONDARY DITCH;	Fabric 4, FELDSPAR
V1480	HS78	ZZ,14.7	60	SSTMG	JAR	ts;icps	UNSTRAT;	Fabric 4, FELDSPAR
V1481	HS78	KG,21.8	118	CHARN		ts;icps	MAIN DITCH;	Fabric 2,
V1482	HS78	QM2,15.5	138	CHARN		ts;icps	EAST OF FORT	Fabric 2,

TSNO	Sitecode	Context	Catalogue No	cname	Form	Action	Description	subfabric
V1483	HS80	WG 2,14.2	61	SSTMG		ts;icps	DEFENCES; MAIN DITCH;	Fabric 4, BIOTITE;SPARSE RQ (MATT SURFACED)
V1484	HS81	,AKG	142	CHARN	JAR	ts;icps	EAST OF FORT DEFENCES;	Fabric 2, ABUNDANT SA Q >0.3MM

Appendix 2

Catalogue No	Sitecode	Context	cname	Action	trench	Description	subfabric
64	HS81	,AGY	MISC	TS(LU)	FORT	Roman FLOOR;	Fabric 7, ANGULAR WHITE SST;SPARSE RQ
75	HH69	3A,T10	ERRA	TS(LU)	VILLA	CENTRE OF ENCLOSURE BETWEEN VILLA AND ROUNDHOUSE; TS24	Fabric 5, ABUNDANT ANGULAR BASIC IGNEOUS ROCK >4.0MM;SPARSE RQ >1.0MM (MATT SURFACED)
13	HH80	,VILLA WELL	ERRA	TS(LU)	VILLA	VILLA WELL; TS17	Fabric 6, BASIC;ACID IGNEOUS;SSTMG
5	HH70	,L10	ERRA	TS(LU)	VILLA	VILLA; TS19	Fabric 9, SA IRON-RICH NODULES >4.0MM;A SA Q;S MUSC
11	HH70	2,X14	SSTMG	ts;icps;TS(LU)	VILLA	VILLA; TS27;NC11	Fabric 2, MUSC
8	HH70	NEQ M10,CS	CHARN	ts;icps;TS(LU)	VILLA	Roman ROUNDHOUSE;SF 188	Fabric 2A, ABUNDANT FINE-GRAINED Q
27	HS78	KK2,21.6	SSTMG	TS(LU)	SECONDARY DITCH	SECONDARY DITCH; TS BY A WOODS STUDENTS	Fabric 4,
14	HH80	VWB,VILLA WELL	MISC	TS(LU)	VILLA	VILLA WELL; TS23;NC14	Fabric 7, FINE-GRAINED WHITE SST;SA AND RQ >0.5MM

Appendix 3

TSNO	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO
V1453	14.99	3.39	0.78	1.33	0.53	1.36	0.53	0.46	0.04
V1454	13.25	4.65	0.99	1.55	0.39	1.66	0.51	0.62	0.12
V1455	14.53	3.82	0.99	1.31	0.6	1.8	0.52	1.08	0.04
V1456	17.71	3.62	1.16	1.51	0.2	1.22	0.48	0.28	0.01
V1457	20.26	4.93	1.18	1.23	1.23	2.95	0.7	0.44	0.08
V1458	16.83	4.12	1.32	0.99	0.57	1.96	0.69	0.29	0.03
V1459	14.86	4.29	1.03	0.96	0.45	2.07	0.59	0.77	0.02
V1460	14.38	2.9	0.78	1.06	0.2	1.35	0.67	0.52	0.03
V1461	17.07	3.44	1	1.77	0.41	1.02	0.63	1.14	0.06
V1462	16.18	4.7	1.34	1.4	1	1.66	0.53	1	0.25
V1463	14.41	2.85	0.83	1.13	0.34	1.27	0.68	1.12	0.03
V1464	14.53	4.7	1.26	0.87	0.61	1.66	0.54	0.61	0.01
V1465	15.52	3.4	0.92	1.48	0.51	1.9	0.53	1.35	0.06
V1466	11.92	4.11	3	1.24	0.47	2.6	0.47	0.82	0.05
V1467	15.43	3.44	1.21	1.92	0.36	1.37	0.51	2.19	0.03
V1468	11.81	4.12	3.21	1.14	0.56	2.98	0.43	0.71	0.05
V1469	13.72	3.51	1.33	1.45	0.9	1.97	0.47	0.83	0.04
V1470	18.67	9.88	2.31	2.07	0.74	2.16	0.6	1.04	0.17
V1471	17.3	5.17	1.45	1.25	0.34	1.85	0.61	1.2	0.07
V1472	12.63	5.97	1.11	5.55	0.53	2.02	0.57	0.92	0.04

TSNO	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO
V1473	12.24	7.28	1.47	1.51	1.19	2.43	0.46	0.64	0.06
V1474	16.87	6.15	1.06	1.45	0.33	1.68	0.58	1.21	0.41
V1475	12.62	7.28	0.8	1.68	0.46	1.45	0.48	1.86	0.04
V1476	11.64	4.16	3.13	1.24	0.54	2.87	0.42	1.06	0.05
V1477	14.01	5.64	2.3	1.22	0.49	2.6	0.53	1.35	0.05
V1478	13.3	6.31	1.14	4.21	0.53	3.24	0.59	0.72	0.07
V1479	17.18	9.95	2.23	1.23	0.22	2.26	0.55	0.81	0.1
V1480	14.3	7.46	1.59	1.31	0.29	2.46	0.51	1.31	0.11
V1481	15.35	7.74	1.94	1.53	0.86	2.52	0.6	0.94	0.18
V1482	17.58	4.84	1.17	1.54	0.43	2.61	0.75	1.89	0.02
V1483	16.05	8.75	1.83	1.47	0.6	2.49	0.6	0.49	0.09
V1484	16.12	4.24	0.91	1.67	0.86	1.43	0.6	1.14	0.25

Appendix 4

TSNO	Ba	Cr	Cu	Li	Ni	Sc	Sr	V	Y	Zr*	La	Ce	Nd	Sm	Eu	Dy	Yb	Pb	Zn	Co
V1453	916	81	25	157	46	18	93	64	48	25	51	111	56	15.8	2.8	8.8	3	47	174	9
V1454	937	76	60	49	50	10	108	58	16	20	36	83	37	6.3	1.1	3.2	1.1	108	122	15
V1455	652	84	32	70	26	13	139	71	17	23	37	82	38	7	1.2	3.5	1.2	48	134	9
V1456	1309	101	29	167	53	19	78	78	47	30	50	122	55	16.5	3.1	8.9	3	42	513	7
V1457	1212	100	52	157	52	17	239	86	35	25	55	122	58	13.1	2.4	6.8	2.3	70	187	15
V1458	734	98	22	80	38	14	106	82	18	50	44	100	45	7.4	1.2	3.7	1.8	39	83	10
V1459	910	87	22	57	53	13	120	78	22	25	44	96	45	8.8	1.5	4.2	1.5	52	87	13
V1460	636	89	16	57	30	13	73	97	19	31	40	89	41	7.4	1.5	3.8	1.4	42	84	9
V1461	1004	94	28	176	53	18	114	70	40	34	56	127	60	15.3	3	7.8	2.5	34	149	9
V1462	1480	87	33	84	56	16	147	84	41	36	57	153	61	14.3	2.6	7.7	2.7	44	175	22
V1463	809	88	31	52	37	14	94	101	31	41	51	114	53	10.5	2	5.4	2.1	33	117	11
V1464	600	83	25	77	35	13	88	88	18	26	35	86	37	7.8	1.3	3.9	1.5	33	98	8
V1465	1173	81	25	75	33	12	152	73	18	25	40	94	41	7.6	1.2	3.7	1.3	51	86	9
V1466	1004	68	23	42	38	10	139	61	18	29	32	70	33	5.8	0.9	3.3	1.4	66	83	13
V1467	1127	87	34	78	48	17	256	77	36	36	46	125	49	12.1	2.2	6.5	2.4	42	172	12
V1468	1065	63	44	49	41	10	128	59	18	27	32	69	33	5.3	0.9	3.4	1.3	28	102	12
V1469	611	70	27	155	48	15	180	65	50	28	47	99	51	11.6	2.3	7.3	2.8	39	139	8
V1470	1186	109	48	93	72	21	185	164	50	46	51	124	56	13.7	2.1	8.3	4	26	178	18
V1471	918	102	26	112	49	17	138	95	29	42	47	111	49	10.5	1.7	5.5	2.3	36	165	14
V1472	696	90	53	39	33	13	181	103	20	36	34	79	35	6.6	1	3.6	1.6	30	96	11
V1473	963	55	18	47	28	9	131	80	21	30	28	69	30	6.3	0.8	3.4	1.7	28	88	10
V1474	1322	96	27	136	61	16	120	81	32	27	45	124	49	11.6	2.1	7.3	2.1	67	234	24
V1475	1376	67	39	103	45	11	180	55	24	25	39	82	40	7.7	1.2	3.9	1.6	40	166	8

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TSNO	Ba	Cr	Cu	Li	Ni	Sc	Sr	V	Y	Zr*	La	Ce	Nd	Sm	Eu	Dy	Yb	Pb	Zn	Co
V1476	1133	64	34	41	40	10	134	59	18	27	31	69	32	5.7	0.9	3.3	1.4	26	119	11
V1477	1533	80	107	79	40	12	148	81	19	26	35	81	36	6.4	1	3.3	1.5	32	189	13
V1478	622	94	43	43	38	13	137	100	21	34	36	86	37	7.7	1.1	3.7	1.6	33	115	12
V1479	1627	111	45	91	72	19	128	162	44	47	50	104	54	12.3	2	7.4	3.6	43	221	15
V1480	1105	87	42	73	47	14	161	115	30	39	42	90	45	9.6	1.4	5.4	2.5	35	146	12
V1481	701	85	33	80	53	16	136	124	34	41	39	106	42	10.1	1.6	6.2	2.8	40	166	18
V1482	997	106	20	85	25	14	203	97	13	32	43	99	43	5.2	0.9	2.5	1.3	39	84	6
V1483	891	97	32	99	52	17	177	139	38	30	45	97	48	11.5	1.8	6.5	2.9	35	125	14
V1484	1119	80	34	234	60	17	167	68	40	24	51	138	55	15.1	2.8	7.7	2.5	54	117	12