Chemical analysis of Roman pottery from Market Rasen

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Objectives

Thin-section analysis and visual study of the Market Rasen pottery indicates that two different clay bodies were used: a fine-textured, silty clay with few sand-sized inclusions, which was used for the Parisian wares (PART), and a coarser-textured clay, containing abundant ill-sorted quartz silt and sand, which was used for greywares (GREY), together with wares with a rounded quartz sand temper derived from the greensand (GRRO), and wares containing sparse to moderate shell fragments, together with a quartz sand similar to that in GREY (VESIC).

One of the aims of the current, chemical analysis was to investigate whether these petrological fabrics had different chemical signatures.

A second aim was to look for patterning within the chemical data which might reveal differences between clay sources used in different parts of the production complex, both within the visual/petrological fabric groups or across these groups.

A third aim was to explore the utility of chemical analysis to characterise these products, which contain few distinctive petrological traits, with a view to studying the distribution of Market Rasen wares at some point in the future.

Methodology

The samples were prepared by removing a large fragment from the submitted object (where sufficient material existed to justify this destructive approach), mechanically removing all exposed surfaces and margins and grinding the remainder to a powder. The resulting powders comprised between 3gm and 5gm. Only a fraction of this sample was actually consumed during analysis but the heterogeneous nature of most archaeological ceramics means that smaller samples are likely to be more variable, as a result of

the presence of non-quartzose inclusions. The samples were numbered (V933-950, V955-9, V963-96) and a record added to a computer database. The unused portion of the samples was returned to the originating body following completion of the project.

The following elements are measured as percentage oxides: Al2O3, Fe2O3, MgO, CaO, Na2O, K2O, TiO2, P2O5 (App 1a). From these, a rough indication of the silica content was obtained by subtracting these percentages from 100%. In addition, the following minor and trace elements are measured, as parts per million: Ba, Co, Cr, Cu, Li, Ni, Sc, Sr, V, Y, Zn, Zr*, La, Ce, Nd, Sm, Eu, Dy, Yb and Pb.

Lead is measured mainly as a guide to potential glaze contamination and because it can indicate where unglazed vessels were fired alongside glazed ones. In this project, naturally enough, all the lead present is thought to have been naturally included in the raw materials.

The dataset was studied using Principal Components Analysis. In this analysis, a series of 14 Principal Components (PC) are computed for each sample. PC1 is that loading which accounts for most of the variation between samples, PC2 the next and so on. For each PC the contribution of each element to the component is also computed. This analysis allows similarities and dissimilarities of each sample's data to be explored.

It is usual to run this analysis several times, excluding elements which dominate the analysis and those elements which are closely linked to such elements (this is particularly true of Ca and Sr) or which may have been affected by leaching or post-burial enhancement (eg P2O5).

For any identified fabric group mean values and standard deviations for each element are calculated and presented.

Chemical analysis

The chemical analysis followed a petrological study of 9 thin-sections and a binocular microscope study of a sample of 63 samples (ie, all of those selected for thin-section analysis plus five extras, excluded from further study for reasons of cost). This petrological study indicated that PART was produced using a quite different clay body from that used for the other wares whereas the main petrological differences in the remaining three fabrics were due to tempering.

The VESIC fabric was tempered with sparse to moderate angular shell fragments, almost all of which had either been leached during burial or destroyed during firing. In the former case there was some recrystallisation within the voids left by the shell fragments and in the latter the formation of a yellowish aluminosilicate, indicating the presence of salt (NaCl) during firing. The ware also contains sparse rounded iron-rich grains and rounded relict clay pellets, some of which are organic. For the purposes of chemical analysis, the leached and unleached sherds are treated separately.

In GRRO the clay had been tempered with moderate quantities of a rounded quartz sand. The surface characteristics and shape of these quartz grains enabled them to be identified as coming from a Cretaceous deposit. In the case of Market Rasen this is almost certainly the Spilsby Sandstone, which outcrops to the east of the site and probably occurs in gravel deposits derived from the Wolds.

In GREY the temper is a much finer sand, in which the grains can be rounded but with dull surfaces, subangular or angular (probably as a result of overgrowth within a sandstone). The characteristics of this sand are similar to those of quaternary wind-blow sand which outcrops extensively in this part of Lincolnshire. Ultimately, the material is derived from Carboniferous, Triassic and Permian deposits to the north and west. Similar sand is present in VESIC, but in lesser quantities.

Many of the sherds were coated with a light brown phosphatic deposit, which included quartz grains, indicating that it had formed during burial in a sandy deposit (ie rather than in an organic midden or cess-pit). The preparation of the samples should have excluded all of the surface coating but thin-section analysis showed that in several cases the pores and laminae in the body were also filled with phosphate. It is inevitable that this will have been included in the chemical samples.

Appendix 1 shows the mean values for the measured elements in these four fabric groups. From this we can see that there are subtle differences in chemical composition between the fabrics, but that in most cases these are less than the standard deviation in values within a fabric, and so cannot be used for classification.

In the case of the fine sand-tempered greyware, GREY, the fabric contains a higher frequency of Pb than any of the other fabrics. Pb can replace Ca in apatite, the main constituent of the phosphate concretions but in the Market Rasen samples is actually inversely correlated with CaO, P2O5 and Ba. Lead is often enriched as a result of glazing, but in this case this is clearly not the case, and in any case the overall frequencies are much lower than in glaze-contaminated samples. The range is 25-65 ppm. Lead occurs in sedimentary deposits in detrital minerals (such as K-feldspars and micas), clay minerals and organic matter. Given that it occurs more frequently in GREY it is likely in this case that the explanation is due to feldspars and micas (Table 1 [Pb]). The relative paucity in GRRO therefore is likely to be due to the different source of sand temper. Lead is least common in the VESIC fabric, irrespective of leaching. From this we might conclude that Pb-bearing micas and feldspars make up a sizeable proportion of the silt in PART.

The only other element to be more common in GREY than in any other fabric is K2O. Potassium is a major constitutent in certain clay minerals, such as illite, as well as being present in micas and feldspars. It is most common in the PART fabric and least common in GRRO. The ratio of Pb to K2O is similar for GREY and GRRO (c19ppm to every 1% K2O) and for the PART and VESIC fabrics (c13-15 ppm). The fact that the ratios differ suggests that not all the Pb and K2O comes from the same source.

GREY is relatively low or average in the frequency of all other measured elements and is particularly low in MnO, which is most common in the leached VESIC samples. The difference between the MnO levels in the leached and unleached fabrics might be a result of leaching of the MnO. Manganese is found in quite high levels in carbonate rocks and may therefore have been present in the shell but there is evidence of MnO staining in the PART thin-sections. There is no indication that this staining is postburial, however, and it is likely that some of the samples contain MnO through this source.

GRRO contains the highest average frequency of MnO. This may be due to the rounded iron-rich compounds present in the fabric The samples are also slightly enhanced in Li, Fe2O3, Silica, Pb and Ni. Nickel is likely to be present for the same reasons as MnO and probably Fe2O3. Nickel, Cu and Fe2O3 are often associated, either in detrital ferromagnesian silicates, crystalline Fe phases, Hydrous Fe and Mn oxides and clay minerals. Lithium, however, is normally present in clay minerals such as illite but the ratio of Li to K2O is higher in GRRO than in other fabric groups, so it is not simply the quantity of clay in the fabric which is responsible for these the variation in Li values. The Li to Al2O3 ratio is also higher for GRRO than other fabrics (109pm for each 1% Al, compared with 89-93ppm in the other fabrics). It should be noted, however, that the highest Li values are in fact found in PART samples. GRRO samples are particularly low in P2O5, Sr, and CaO, all of which are associated with calcareous and phosphatic concretion.

The PART samples have high frequencies of almost all measured elements. A proportion of this enhancement may be simply a reflection of the slightly lower silica content in these samples. In most cases these elements are correlated with Al2O3, and therefore present in the clay mineral fraction. However, even taking this into account (by normalising the analyses for Al2O3), there are still some elements which are enhanced in PART. These are firstly Zn followed by MgO, TiO2, V, K2O, Co, Na2O and Sc. There is also relative depletion in the light rare earth elements (Nd, Eu, La, Ce and Y) and in some metallic elements (MnO, Cu, Ni, Fe2O3 and Pb) and in Ba and CaO. The low values for Ba and CaO are simply due to the presence of shell temper in VESIC and there is little difference in the metallic element frequencies, relative to Al2O3, in GREY and PART, again pointing to these elements being enhanced in GRRO and the VESIC fabrics.

Zinc is clearly more common in the PART samples (Table 2). It has similar associations in sediments to Ni, Cu and Fe2O3 and yet is enriched in the Parisian ware fabric whereas those elements are relatively depleted. This is likely to be due to it's affinity for organic matter, since most of the PART samples have carbon-rich cores in thin-section, suggesting that they were produced from an organic clay (the carbon runs throughout the body and is not the result of firing in a smoke-rich kiln). Accordingly, the firing pattern of the samples was noted (broadly classified as 'black', 'grey' and 'oxid') and the frequency of Zn plotted against firing. This showed that the differences in Zn content were not related to the current presence of organic matter and therefore if they are indeed related to a higher organic content in the fabric then this is in turn due to a difference in the parent clay, not the fired fabric. However, when the PART samples are analysed site-by-site this shows a clear difference in Zn content by site with the

high values coming from MRA65 only (Table 3). This is a perplexing result, in that MRA65 is part of the same site as MRA66, where both the PART and GREY samples have lower Zn values. The mobility of Zn means that it is unwise to use this evidence to indicate the use of different batches of clay.

Vanadium (Table 4) is associated with resistate minerals (detrital Fe oxides and ferromagnesian silicates), organics complexes, hydrous oxides and clay minerals. There is no comparable evidence for site-specific variation in V content however and therefore it is more likely that the element was present in the original raw materials, probably as a result of higher organic content.

Cobalt has similar associations to the other metals (such as Ni) and is usually correlated with Mn and Fe (BGS 1996, 48-9). However, there is only a weak correlation between Ni and either of these elements in the Market Rasen data. Instead, PCA suggests a correlation with Na2O3. Plotting Co against Na2O3 shows a stronger correlation between these elements for PART than for the coarsewares. It is enriched in PART but not to the same extent as V or Zn (Table 5). Furthermore, it is also higher in VESIC than in the remaining coarsewares. This might suggest a correlation with organic matter but there is little evidence for post-burial contamination, in terms of site-specific enhancement and therefore the element is likely to have been present in the raw materials.

Magnesium values are on average higher in PART than in the other fabrics. Although present in accessory minerals such as pyroxenes, amphiboles and micas. The correlation with K2O seems to indicate that it is present either within micas or clay minerals. There is no evidence from the thin-section analysis for the presence of dolomite, another major source of MgO in sedimentary deposits. Interestingly, MgO, like Zn, is often associated with organic deposits.

Under reflected light microscopy it can be seen that the PART fabric contains moderate silt-sized Titanium oxides and these are the source of the TiO in the chemical analyses. It is possible that both V and Co are present in these oxides. Zirconium, which is also higher in PART than in other fabrics, is also likely to be present as silt-sized zircon grains.

The explanation for the relatively high Na2O values in PART is not clear. The petrological study has noted that salt must have been present in the raw clay used to produce the VESIC fabric, in order to give rise to the aluminosilicate alteration product. However, even if present in the form of NaCl in the raw PART clay, NaCl is soluble in water and decomposes on heating, so in either case would not survive firing. It is more likely, therefore, that in PART the enhanced Na2O values are the result of the presence of plagioclase feldspar, or accessory minerals such as tournaline in the silt fraction.

Finally, the chemistry of the VESIC fabrics can be considered. Taking the leached fabric first, both the raw values and those normalised for Al2O3 are either average or below average for the Market Rasen fabrics. In other words, there are no elements which are relatively enhanced in these samples. By contrast, in the unleached samples, in which shell is still present, there is significant enhancement in a range of elements, relative to the leached samples. In many cases it is quite clear that these enhanced

elements are associated with the shell inclusions. The main difference is in the CaO (21% higher in the unleached samples) and in Sr (15%). Phosphorus is also enhanced (19% higher) and there seems to be no reason why this should be so if its source was post-burial phosphate concretion since both the leached and unleached samples contain voids which could have been filled with phosphate. A breakdown of P2O5 content by fabric and frequency shows that four of the five fabric groups have bimodal distributions in their P2O5 content (Table 6). This suggests that perhaps values in the order of 0-1.5% are present in the raw materials and the remainder are due to post-burial enrichment. The natural sources could include fish bone and phosphatic nodules, both of which are common in Cretaceous deposits in the Lincolnshire Wolds. In some cases the frequency of an element which was lower than average in the non-vesicular fabrics was higher in the unleached VESIC samples. In these cases, the element was already enhanced in the leached VESIC samples and must therefore have been present in the shell inclusions. These elements include: Ba, Na2O and rare earth elements. In comparison to the other sandy coarsewares (GREY and GRRO) the rare earths are enhanced both in the leached and unleached VESIC samples, again suggesting that they were present at a relatively high level before leaching. It seems from these analyses that the leached inclusions consisted of calcite shells (accounting for CaO, Sr, Ba) and either phosphate nodules or phosphatic shells (accounting for P2O5 and the rare earth elements).

Across all the Market Rasen samples Ba appears to be correlated with CaO and is known to substitute for Ca in calcite (BGS 1996, 34-5). There is also a correlation between Ba and P2O5 and this might suggest that it is occurring in the Market Rasen samples in apatite. Cryptocrystalline phosphate (collophane) was observed in thin-section coating some of the samples and lining pores and laminae within them. Interestingly, Sr, which is normally highly correlated with CaO, is more common, relatively, in the fineware fabric. A plot of Sr against CaO shows that the samples fall into two ratios (Table 7). The PART samples, together with most of the GREY samples and a few GRRO and VESIC samples have Sr to CaO ratios in the range 15 to 25 ppm Sr for every 1% CaO whereas most of the GRRO and VESIC samples have ratios between 9 and 15.

Discussion

Fig 1 shows a PCA plot based on an analysis of the mean values of the measured elements. It shows that based on all these elements the fabrics are equally dissimilar, each (apart from the leached VESIC samples) having one or more characteristic elements:

GRRO: 'Silica'

GREY:Pb, Li

PART: Mg, Cr, Sc, K2O, Al2O3, TiO2 and V

VESIC: Yb, Eu, Dy, Y, Cu, Sr, P2O5. CaO, Ba, Ni, MnO, Fe2O3

The relationship of individual samples to these idealised means is shown by undertaking PCA for the whole dataset. Fig 2 shows a plot of PC1 versus PC2 for this dataset and indicates that whereas about half of the PART samples have a distinctive fabric, quite separate from the remainder, the rest overlap with VESIC (leached and unleached). This could be interpreted as showing the accidental presence of sand or other inclusions in the PART fabric. However, the chemical separation of the two groups is particularly strong, in many cases with no overlap in values for elements (Table 8).

TSNo	Site Code	MJD No	Form
V0977	MRGF68	TS45	CLSD
V0981	mrc65	TS49	BK
V0982	mrc65	TS50	CLSD/ROUZ
V0984	mrc65	TS52	CLSD
V0985	MRA66	TS53	CLSD/ROU
V0986	MRA66	TS54	CLSD
V0987	MRA66	TS55	CLSD
V0988	MRA66	TS56	CR SURF
V0990	mrc65	TS58	CLSD/ROUL
V0995	MRA65	TS63	CLSD/WASTER

GRRO and GREY likewise have overlapping distributions on this diagram, indicating a basic similarity in fabric. Here, though there is also an overlap with the leached VESIC samples. The compositions of the Principal Components are very similar to those generated by the mean value dataset. Plotting PC3 against PC1, however, shows that there is a combination of element weightings which separates GRRO and PART from each other and from the remaining fabrics although here too it is not possible to obtain a separation of the GREY and VESIC samples.

We can now address the main objectives of the discussion. The petrological fabric groups do indeed have different chemical signatures and in most cases these can be understood in terms of their petrology. There is very little evidence for post-burial enhancement but clear evidence for the effects of leaching on both calcareous and (postulated) phosphatic inclusions.

As noted above, there is some evidence for the presence of a chemically distinct fabric for some of the PART ware (Table 8). This division cannot be seen in thin-section. Otherwise, there is no clearcut evidence for chemical subgroups within the petrologically-defined fabrics.

The ability to recognise Market Rasen ware using chemical signatures can only really be tested with comparative data, which should be of two kinds: vessels which are thought to be Market Rasen products but found on consumer sites and vessels of similar petrological characteristics which are certainly not produced at Market Rasen. The only available comparative data is for medieval pottery from sites in north Lincolnshire, from which three datasets have been selected as a test:

- a group of silty loom weights from Flixborough. These are almost certainly made from Humber/Trent estuarine clay and might therefore be similar in origin to the parent clay of PART.
- b) A group of Torksey-type sherds from Flixborough. These were presumably produced from a Jurassic clay tempered with a sand similar to that in GREY (and VESIC).
- c) Samples of clay artefacts and natural clay from Barton-upon-Humber. The artefacts are almost certainly produced at Barton. The inclusions are perhaps more abundant than in GREY and certainly more abundant than in VESIC but are otherwise similar in appearance.

No material which is visually similar to GRRO has yet been analysed using ICPS.

For the silty loom weights, a PCA analysis showed that the weights contain higher quantities of Na2O and enhanced values for Cu and MgO, Fe2O3, La, Ce, Ni, Y.

Adding the Torkey wares also produces a clear distinction between the Flixborough finds and the Market Rasen wares when analysed using PCA. The main differences are in MgO, Cu, Na2O, Y Fe2O3, La and Ce. These are the same elements which differentiated the loom weights (which were included in this analysis too). Although the loom weights and Torksey sherds are visually quite different in texture and in their use of raw materials this analysis only partially separates the two groups, whilst there is a wide gap between the Flixborough finds and those from Market Rasen.

Finally, the addition of the three Barton samples shows that they too can be separated from the Market Rasen ones, although the clay sample, V740 is similar in composition to some of the Market Rasen samples and plots on the fringe of the Market Rasen cluster (Fig 3). There is no difference in the distinguishing elements or in their relative order from that achieved in the previous PCA analysis.

A similar analysis using unpublished data for various fine-textured early Roman wares produced in London (LOND, LOMI) showed that these too could be distinguished from the Market Rasen products.

We can therefore show that the Market Rasen wares are distinguishable from other silty and sandy wares produced at the mouth of the Ancholme valley and at the mouth and well upstream in the Trent valley. The next stage in this project, therefore, ought to be the sampling of sherds of possible Market Rasen products found on consumer sites. In addition, should any other fired clays known to have been produced in the Ancholme valley be discovered they too should be included in future analysis.

Characterisation of the Parisian wares form a distinct, and potentially more interesting, problem. As part of the current study it has been established that the Market Rasen Parisian wares are chemically distinguishable from those produced in the City of London. However, typological analysis suggests that this, whilst technically interesting, is not a significant archaeological problem since there is no reason, looking at the typology of finds in the midlands and north of Britain, to believe that London-made finewares ever travelled into this region, nor to suggest that Market Rasen wares travelled that far south.

However, there is a significant possibility that finewares of Parisian type produced in the Nene Valley industry and at Rossington Bridge, near Doncaster, have distributions which overlap with those of the Market Rasen ware, even at nearby sites such as Lincoln. Despite the fact that Parisian ware was first identified on sites north of the Humber there is as yet no evidence for the production of the ware in that region. Market Rasen would be a possible source for these wares, based on trade by boat down the Ancholme, or using the road system and crossing the Trent at Littleborough or the Humber at Brough. However, we know that Nene Valley products in the 3rd and 4th centuries are the dominant fineware in Yorkshire whilst Rossington Bridge too is situated in a location where either riverine or road distribution into Yorkshire is possible. The next stage of this project should therefore be to determine whether or not Nene Valley and Rossington Bridge finewares of Parisian type can be distinguished from Market Rasen ware and, depending on the results of that study, examining examples from consumer sites in Lincolnshire and Yorkshire.

List of Illustrations

- Fig 1 PCA plot of PC1 versus PC2 for the average values for the four fabrics (with the VESIC samples subdivided according to leaching).
- Fig 2 PCA plot of PC1 versus PC2 for all analysed samples
- Fig 3 PCA plot of PC1 versus PC2 for all analysed samples, plus comparative material from Flixborough (loom weights and Torksey ware) and Barton-upon-Humber (clay sample and artefacts probably produced from similar clay).
- Table 1.Distribution of Pb values by fabric group
- Table 2.Distribution of Zn values by fabric group
- Table 3.Distribution of Zn values by site group
- Table 4.Distribution of V values by fabric group
- Table 5.Distribution of Co values by fabric group
- Table 6.Distribution of P2O5 values by fabric group
- Table 7. Sr to CaO ratios
- Table 8. List of samples in PART sub-group

Tables

Table 1

PB ppm	GREY	GRRO	PART	V	ESIC	Grand Total
25-30				1	5	6
30-35	3	3 1		6	3	13
35-40		2	ŀ	6	4	14
40-45	3	3 2	2	4	2	11
45-50		1		5		6
50-55	3	3 1				4
55-60	2	2				2
60-65	1					1
Grand Total	12	2 9		22	14	57

Table	2
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ZN ppm	GREY	GRRO	PART	VESI	С	Grand Total
50-60	1				1	2
60-70	2	2	4		1	7
70-80	5	; .	4		1	10
80-90	2	2		2	2	6
90-100	1		1	2	2	6
100-110	1			6	1	8
110-120				3	5	8
120-130				5		5
140-150				1	1	2
160-170				1		1
170-180				1		1
180-190				1		1
Grand Total	12		9 2	22	14	57

ZN	MRA65	MRA	i 66	mrc65	MRC	GF68	Grand Total
80-90			1			1	2
90-100					1	1	2
100-110			3		3		6
110-120		2			1		3
120-130			4		1		5
140-150		1					1
160-170		1					1
170-180		1					1
180-190		1					1
Grand Total		6	8		6	2	22
Mean Zn	150	.20	111.43	106.9	93	90.25	118.85

Table 3

V ppm	GREY	GRRO	PART	VES	IC	Grand	Total
100-109					1		1
130-139	4		1		3		8
140-149	4		5	1	7		17
150-159	1	2	2	2	1		6
160-169	3	i		7	1		11
170-179			1	2	1		4
180-189				3			3
190-199				6			6
200-210				1			1
Grand Total	12		9 2	22	14		57

Table	5
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со	GREY	GRRO	PART	VESI	С	Grand Total
9-9		Į				1
10-10		l				1
11-11	3	3			1	4
12-12	-	l			2	3
13-13	2	2		1		3
14-14	1	1 2	2		1	4
15-15		:	3		2	5
16-16	1	I :	3	3	1	8
17-17				3	2	5
18-18				3	2	5
19-19				5		5
20-20	1		1	2	2	6
21-21	1	I		2		3
22-23				3	1	4
Grand Total	12	2 9	э :	22	14	57

]	Table 6					
	P2O5 %	GREY	GRRO	PART	VESIC	VESIC
_					leached	
	0-0.5	6	8	8	3	
	0.5-1	1	1	1	3	
	1-1.5	1		4	1	2
	1.5-2			4		1
	2-2.5	2		5	2	2
	2.5-3	1				1
	Grand Total	11	9	22	9	6

sr:cao	GREY	GRRO	PART	VESIC	Grand Total
0.09-0.1				2	2
0.1-0.11		:	2	2	4
0.11-0.12		:	2	1	3
0.12-0.13			1	2	3
0.13-0.14				1	1
0.14-0.15			1	1	2
0.15-0.16		1		1	2
0.16-0.17			1	1	2
0.17-0.18				1	1
0.18-0.19				2 1	3
0.19-0.2		1	1	2	4
0.2-0.21		1		6 3	10
0.21-0.22	į	5		2 1	8
0.22-0.23				2	2
0.23-0.24		1	1	3	5
0.24-0.25		2		2	4
Grand Total	1	1 9	9 2	22 14	56

Table	7
1	

Appendices

Appendix 1: Mean values for the fabric groups

Elemen t	GREY		GRRO		PART		VESIC	leached	VESIC	
	mean	sd	mean	sd	mean	Sd	mean	sd	mean	sd
a) Major elements (Percent)										
SIO2	72.30	1.54	73.44	2.10	68.23	1.65	70.60	2.65	69.51	2.03
AL2O3	16.37	1.02	15.43	1.68	18.51	1.57	16.96	1.36	15.80	1.37
FE2O3	5.27	0.64	6.38	0.79	6.08	0.53	6.30	0.84	6.36	0.85
MGO	0.82	0.15	0.74	0.11	1.01	0.18	0.82	0.10	0.88	0.24
CAO	0.76	0.26	0.68	0.20	0.97	0.33	1.00	0.37	2.15	0.38
NA2O	0.21	0.03	0.16	0.02	0.24	0.03	0.21	0.02	0.23	0.04
K2O	2.55	0.21	2.08	0.26	2.88	0.32	2.42	0.18	2.39	0.17
TIO2	0.73	0.07	0.68	0.09	0.86	0.10	0.73	0.05	0.67	0.11
P2O5	0.95	0.92	0.34	0.12	1.16	0.83	0.91	0.70	1.93	0.60
MNO	0.03	0.04	0.08	0.06	0.07	0.05	0.06	0.03	0.10	0.03
b) Minor and trace elements (ppm)										
BA	432.27	81.40	499.56	111.96	523.09	114.57	527.11	100.32	703.83	68.11
со	13.55	3.96	15.67	1.80	18.64	2.41	15.33	3.46	16.83	3.25
CR	107.18	9.45	101.00	14.19	120.77	12.07	110.00	9.38	103.83	12.16
CU	20.27	5.37	21.67	5.20	22.95	3.12	21.78	3.27	24.33	4.97
NI	41.73	7.02	50.00	9.51	49.27	4.24	49.44	7.35	52.67	8.16
SC	14.18	1.17	13.22	1.20	16.68	1.45	14.89	1.27	14.00	1.10
SR	164.82	59.24	90.56	13.23	197.23	67.78	149.22	66.48	284.00	45.88
V	147.64	12.22	147.89	13.06	176.82	17.50	149.56	11.65	133.50	12.82
ZN	76.80	12.22	72.47	10.38	118.85	27.86	80.66	18.41	116.83	13.50
ZR*	64.00	7.27	65.89	5.18	82.73	9.21	75.33	10.78	77.83	12.30
LA	36.36	2.94	35.00	5.41	41.59	3.80	39.33	4.06	39.50	3.27
CE	65.36	6.44	63.89	9.01	77.82	7.44	74.44	9.38	77.50	9.52
ND	36.87	2.97	35.69	5.34	42.53	3.67	40.04	4.22	40.81	3.49
SM	4.55	0.69	4.38	0.72	5.39	0.57	5.01	0.77	5.41	0.73
EU	1.20	0.16	1.18	0.15	1.45	0.14	1.32	0.17	1.52	0.23
DY	2.86	0.47	2.97	0.40	3.65	0.25	3.27	0.48	3.92	0.69
YB	1.76	0.21	1.84	0.19	2.20	0.15	2.06	0.23	2.22	0.23
PB	48.32	9.48	40.54	6.13	38.67	5.55	33.22	5.27	35.05	7.07
LI	67.09	14.63	73.89	10.71	77.18	17.89	68.33	8.09	59.67	13.40
Y	13.91	2.63	14.11	2.71	17.45	1.57	16.11	1.96	19.83	3.06