Petrographic analysis of some cooking wares from Zeugma, Turkey

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1. Samples

This report presents the petrographic characterisation of a selection of cooking wares from Zeugma, Turkey. Two batches of samples were received (Table 1). The first of these comprised 15 samples which were referenced as ASM1-ASM15. Of these, ASM1 and ASM2 were unfired clay and were therefore not suitable for thin section preparation.

The second batch comprised 7 ceramic samples identified as 16 (now AMS16), D1, D2, D3, D4, P1 and P2. P1 and P2 are glazed buff wares but P2 was too friable for thin section preparation. Instead the petrography of P1 and P2 was determined by scanning electron microscope (SEM)

Table 1 - Sample details and main fabrics

I.D.	Sample	Preparation	Main fabric type	Fired colour
AMS1	Clay sample	Not prepared		
AMS2	Clay sample	Not prepared		
AMS3	Earthenware	Thin section	Limestone + volcanics	Buff
AMS4	Earthenware	Thin section	Limestone + volcanics	Buff
AMS5	Earthenware	Thin section	Limestone + volcanics	Buff/Red
AMS6	Earthenware	Thin section	Limestone + volcanics	Buff
AMS7	Earthenware	Thin section	Limestone + volcanics	Buff
AMS8	Earthenware	Thin section	Limestone + volcanics	Buff/Red
AMS9	Earthenware	Thin section	Limestone + volcanics	Buff
AMS10	Earthenware	Thin section	Limestone + volcanics	Red
AMS11	Earthenware	Thin section	Limestone + volcanics	Red
AMS12	Earthenware	Thin section	Quartz tempered	Red
AMS13	Earthenware	Thin section	Quartz tempered	Red
AMS14	Earthenware	Thin section	Limestone + volcanics	Buff/Red
AMS15	Earthenware	Thin section	Limestone + volcanics	Red
AMS16	Earthenware	Thin section	Limestone + volcanics	Buff
D1	Earthenware	Thin section	Quartz tempered	Red
D2	Earthenware	Thin section	Quartz tempered	Red
D3	Earthenware	Thin section	Limestone + volcanics	Red
D4	Earthenware	Thin section	Quartz tempered	Red
P1	Glazed earthenware	SEM analysis	Igneous, metamorphic + recycled glaze etc	pale buff
P2	Glazed earthenware	SEM analysis	Igneous, metamorphic + recycled glaze etc	pale

2. Fabric summary

Figure 1 summarises the main fabric divisions. The results show that there are 3 main fabric groups and one intermediate/sub-group; these are:

a) *Limestone/Volcanic Red-firing*
ASM 10, 11, 15, D3 (and subgroup ASM 5,8,14) Initially all of these can be assigned to a single broad fabric. This has a reddish matrix (or in the case of the subgroup, the ability to fire to reddish) with a range of natural inclusions derived from the weathering of basic volcanics (andesite +/- basalt), acid igneous volcanics and/or intrusives (dacite/granodiorite), limestone and chert. Within this broad fabric group there are variations in the relative proportions and sizes of inclusions, but a

consistent set of minerals is represented. There are also many intermediate alteration products (i.e. minerals in the process of weathering to clays). While further examination is likely to suggest sub-fabrics, this broad fabric group can be considered to accommodate the level of variation which would be expected within the clay deposits in use here.

b) *Limestone/Volcanic Buff-firing*
ASM 3,4,6,7,9,16 - these have a similar set of inclusions (volcanics, chert and limestone) though in differing proportions, but their common feature is the buff matrix. This matrix colour reflects a high content of fine inclusions (and in particular of carbonate).

c) *Quartz tempered red-firing*
ASM12, ASM13, D1, D2 and D3 - this is a distinctive fabric in which a very fine red clay has been tempered by a sand made up almost entirely of strain-free monocrystalline quartz. The microtexture of the quartz grains suggest that these have been derived from a sedimentary quartzite or vein quartz source. This is identical to Agnes Vokaer’s Fabric 2.

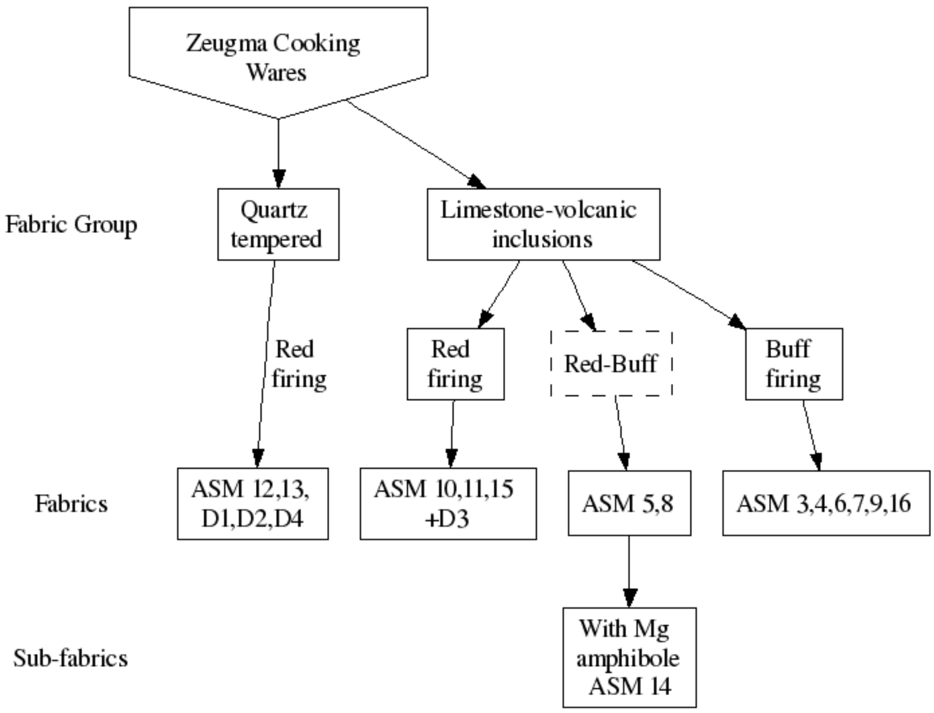

Figure 1 - Fabrics groups, fabrics and sub-fabrics.

3. Petrographic Details

3.1. ASM 3

The fabric is buff-coloured and has a fine-sandy matrix. Inclusions have a mean grain size of 0.75mm, and a maximum of 1.25mm. Limestone grains are of micrite, microsparite and foraminifera, with no evidence for thermal decomposition. Volcanics minerals (plagioclase and clinopyroxene) are basalt-derived and weathered basaltic material is present as ferruginous/opaque grains. Small amounts of chert, quartz, and potassium feldspar are also present.

3.2. ASM 4

This is a naturally fine-sandy clay which has inclusions of limestone, andesite and (lesser) acid igneous volcanics in a carbonate-rich matrix. The fabric is fine, with inclusions less than 0.5mm in diameter. Limestone is represented by grains of microsparite and microfossils (foraminifera). Some of this material is relatively recent, as it forms a cement around volcanic sand grains. Chert is also present and is probably derived from the same limestone outcrops.

Volcanic grains comprise calcium amphibole (hornblende), plagioclase, minor clinopyroxene and lithic fragments (andesite). An acid igneous component (i.e. "granitic") is also present, being represented by quartz, potassium feldspar and pumice.

3.3. AMS 5

This fabric differs from ASM4 in being very slightly coarser (maximum grainsize 1mm, mean 0.5mm), more oxidised, and having less fine-grained carbonate in the matrix. There is a slight bimodality of grainsizes which is often an indication of added temper. However, in this case it is still considered that this is a naturally fine-sandy clay, and that no temper has been added.

Inclusions are of quartz, limestone (microsparite and micrite), foraminifera, altered basalt, calcium amphibole (hornblende), trachyte, a few fragments of volcanic ash (tuff), epidote, chert, goethite, serpentine and metamorphic composite grains (quartz-muscovite).

Overall these inclusions are medium-sorted. Limestone inclusions are moderately-well rounded but other grains are more angular. The weathered basalt fragments show little evidence for having been transported any distance by streamflow, suggesting that the clay used was not very far from a basalt outcrop.

3.4. AMS 6

This is broadly similar to ASM5 but with a few potentially significant differences. The fabric is very slightly coarser (max 1.5mm, mean 0.5mm) and again there is a slight bimodal size distribution. As with ASM 5, the matrix is does not have a high concentration of fine grained carbonate.

Limestone grains are of microsparite, biomicrite and foraminifera, and these show a greater range of textures than for ASM 5. Volcanic grains are abundant and consist of clinopyroxene, altered basalt, serpentine, zeolites, and rare chromite, Ca-amphibole and trachyte. The form of the serpentine/clay aggregates suggest that these may have been vesicle infills.

An important difference is that the basic igneous rock represented here is a basalt, whereas that of AMS 5 is of a more intermediate composition (e.g. an andesite).

3.5. AMS 7

The orange-buff firing colour of this fabric reflects the underlying high carbonate:siliclastics ratio. Inclusions are less than 0.5mm in size, have a high to medium angularity are interpreted as natural, not added temper. Limestone inclusions are of microsparite and there is a small amount of recent carbonate cement which has enclosed sand grains. Volcanics are mainly andesitic (plagioclase and calcium-amphibole) though there is some highly weathered basalt. Also there is a minor acid igneous component as indicated by quartz and quartz epidote). Other sand grains include chert and rare angular fragments of mica (muscovite) schist.

3.6. AMS 8

The reddish colour of this fabric suggests a lower content of fine-grained carbonate in the matrix: this is confirmed in thin section. Inclusions are of less than 0.5mm maximum diameter, the very fine grain size suggesting that these inclusions are natural rather than added temper.

Limestone (carbonate) grains are mainly of rounded micrite. This fine-grained texture may be largely secondary as most grains show evidence for thermal decomposition (an indication of a relatively higher firing temperature).

Other inclusions are of chert, clinopyroxene, calcium amphibole, subhedral plagioclase, trachytic groundmass (aligned plagioclase laths), basalt (undifferentiated) and the secondary products of basalt weathering (goethite, ferruginous clays, serpentine). A small amount of metamorphic material is represented by composite quartz-muscovite grains which show a well developed preferred orientation.

3.7. ASM 9

The high proportion of fine but poorly-sorted inclusions suggests the use of a colluvial clay for this fabric. Inclusions have a mean grain size of 0.5mm, with a maximum of 0.7mm. Limestone types include micrite, microsparite and foraminifera. None show any evidence of thermal decomposition, an indication a of lower and/or shorter firing than for ASM 8. Volcanic inclusions consist of calcium amphibole, plagioclase, altered undifferentiated basalt, goethite/ferruginous clays, and serpentine. Acid igneous rocks are represented by quartz and potassium feldspar (orthoclase), and quartz is also present as composite grains with epidote, and as fragments of metamorphic rocks (schists). A single tourmaline was observed.

3.8. ASM 10

This is a very reddish fabric in which there is a conspicuous bimodal distribution of inclusions, possibly suggestive of tempering (by clay mixing). Limestone grains are abundant and consist mainly of micrite, with lesser microsparite and foraminifera. Included are a few rounded grains of micrite with microsparite cores. These indicate that much of the observed micrite has developed due to thermal decomposition of coarser carbonate grains. Volcanics are very common and are of basalt (undifferentiated), trachytic basalt, calcium-amphibole and altered basalt (ferruginous clay, fine-grained iron oxides and serpentine),

3.9. ASM 11

This fabric is similar to that of ASM 10 but has a lower inclusion content and more silt/fine sand in the matrix. The bimodal size distribution is again suggested but is less clear cut. Firing temperature seem to be same as for ASM 10 with carbonate grains again showing evidence for thermal decomposition. The inclusions types are as for for ASM 10.

3.10. ASM 12

This is a very different fabric from ASM 3 to ASM 11. Here a reddish and relatively inclusion-free clay has been tempered with an unusually pure quartz sand. Whereas most quartz sands consist of a mix of different types of quartz grains, here only one type of quartz is present. Quartz grains are monocrystalline and strain-free, less than 0.5mm in diameter and are angular or sub-rounded in shape. Many have pronounced facets/crystal faces which makes them look similar to igneous euhedra. However, the presence of growth zones suggest that instead these have been derived from the disaggregation of a mass of vein quartz or weak sedimentary quartzite.

The purity of this quartz sand is a strong argument from it having been added as a temper. A natural river sand would be expected to have a more mixed quartz population, and at least a few non-quartz inclusions.

3.11. ASM 13

This fabric is essentially the same as for ASM 12 in composition, but there are some minor differences. Again the fabric consists of a very reddish clay which has been tempered with strain-free monocrystalline quartz of a vein or sedimentary quartzite source. In total there is slightly less quartz temper than for ASM 12 and the material is slightly finer.

One interesting difference is that here the reddish clay has a few very fine inclusions of plagioclase feldspar and chert. This suggests that quartz temper has been added to an iron-rich clay which has been derived from a volcanic source.

3.12. ASM 14

A slightly coarser limestone-volcanic fabric with a mean grain size of 0.5mm, but with a few (mainly angular chert) grains up to 1.5mm. Although similar in most respects to the other fabrics with limestone and volcanic inclusions, this fabrics is slightly different in that it contains colourless magnesian amphibole in addition to the usual pleochroic calcium variety.

This fabric is also characterised by a very high total inclusion content, visually estimated at 40%. Inclusions are of micrite, sparite, chert, amphibole (above), clinopyroxene, plagioclase, altered andesite and basalt, granophyre and minor quartz-mica schist. The size, shape, types and amounts of inclusions in this fabric suggests that this is based on a colluvial clay.

3.13. ASM 15

A reddish fabric with a high inclusion content (inclusions 0.5mm mean diameter). The usual limestone and volcanic grains are present, but there is also some coarser calcite. The latter is slightly more rounded than the other inclusion types and probably represents calcite vein material.

3.14. ASM 16

The matrix is buff suggesting the presence of fine-grained carbonate and/or a lower content of fine ferruginous material from weathered basalt. Carbonate grains are now all fine-textured as a result of thermal decomposition, but some original outlines of foraminifera can be seen. Volcanics are represented by altered basalt and fresher trachytic material. Acid igneous - derived inclusions include quartz and zoned orthoclase, suggesting a dacitic parent rock.

3.15. D1

This is a reddish fine-grained fabric. The matrix has a small amount of very fine inclusions, these are all less than 0.1mm and are mainly quartz but with an occasional plagioclase feldspar. Added temper consists of the same type of monocrystalline and strain-free quartz as described elsewhere, having a mean grain size of 0.5mm, and a maximum of 1mm. However, the source of this quartz is not so clear cut in this case. Whilst most of this seems to be derived from a vein or sedimentary quartzite, there is also a smaller component of larger quartz grains which are more rounded. Some of these appear to be embayed, suggesting that they may be phenocrysts derived from a dacitic or rhyolitic lithology. This is supported by the presence of a few grains of devitrified acid igneous groundmass which also include (parts of) quartz euhedra.

3.16. D2

A reddish quartz-tempered fabric with the usual monocrystalline quartz, as inclusions of 0.5mm mean grainsize, max 0.75mm. Oxidation here is limited to the outer surface only, the main part of the body remaining dark. The matrix does not contain plagioclase.

3.17. D3

A reddish fabric but one with limestone and volcanic inclusions (mean 0.75mm). All limestone grains are now fine grained as a result of thermal decomposition. Basalt inclusions are relatively un-weathered and can be seen to be of an ophitic variety. Also present are small grains of trachytic groundmass, granodiorite and myrmekite. This indicates the presence of felsic igneous sources in addition to the volumetrically more significant basaltic one. Chert and schist also form a minor component.

3.18. D4

This is a reddish fabric tempered by monocrystalline quartz (mean 0.5mm, maximum 1.0mm). Also present is a small amount of devitrified igneous groundmass similar to that noted in D1.

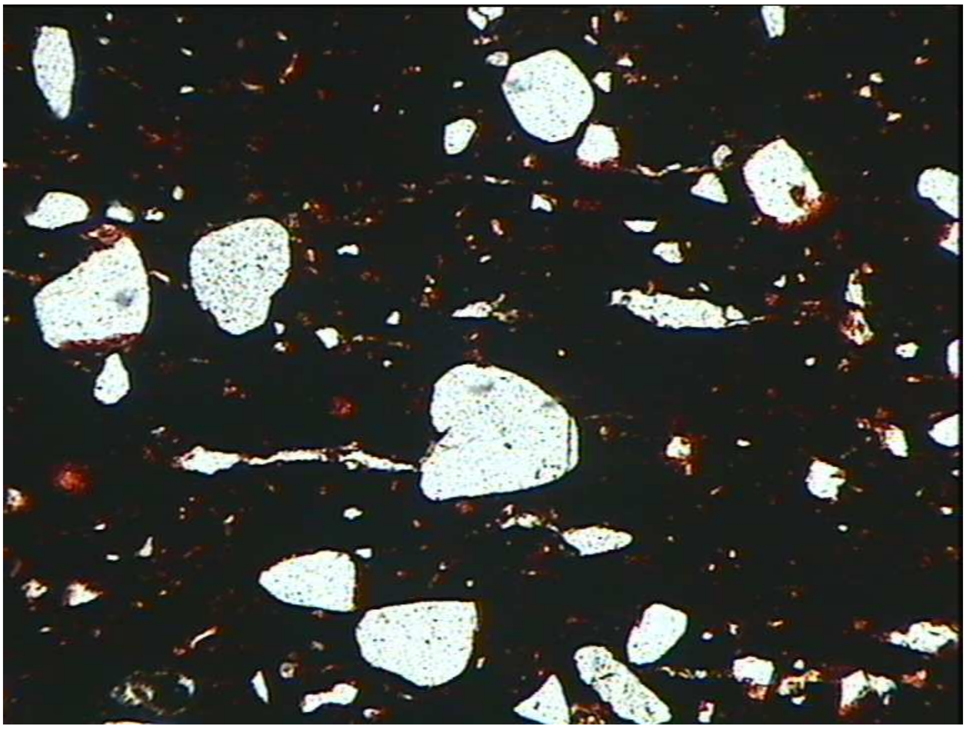

Figure 2 - ASM 12 showing monocrystalline quartz temper in a non-silty matrix (ppl, magnification x40).

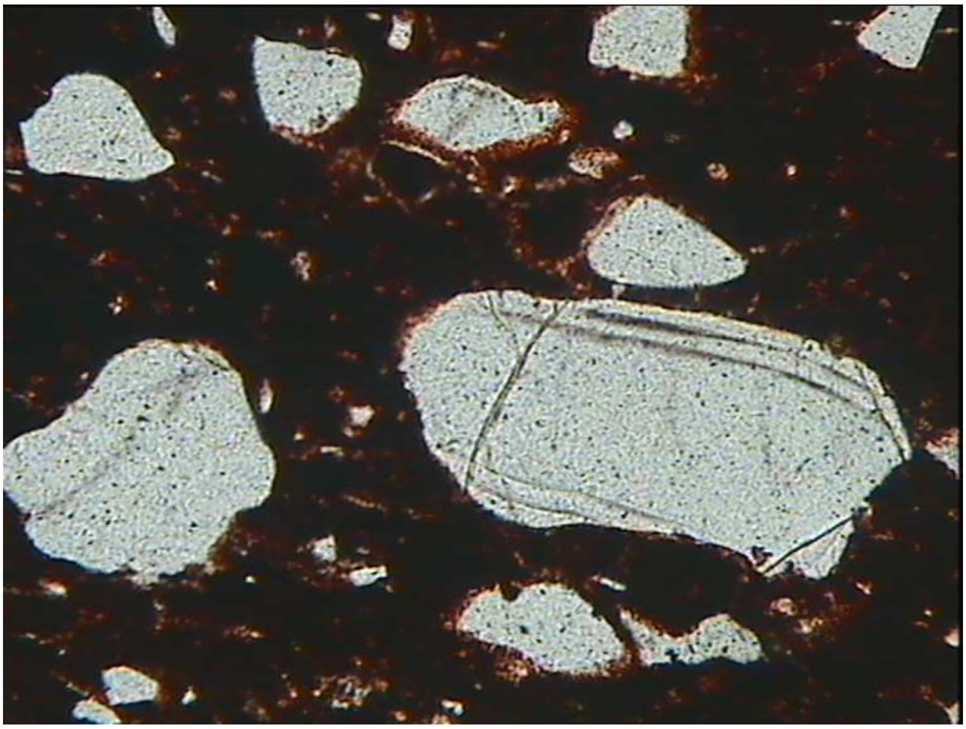

Figure 3 - Detail of ASM 12 showing slightly curved growth lines parallel to the long-axis of the larger quartz grain.These quartz grains are interpreted as being derived from a vein or weak sedimentary quartzite source, and were added as temper to a reddish clay derived (at least in part) from the weathering of a basalt (ppl, magnification x100).

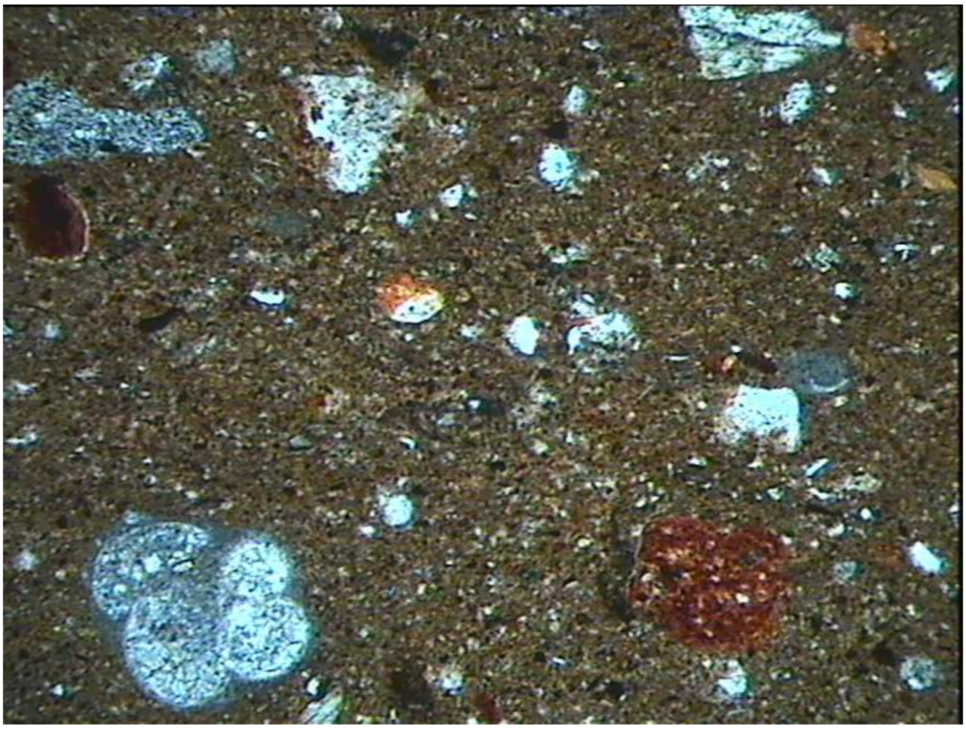

Figure 4 - ASM 3, a buff-firing fabric with limestone and volcanic inclusions. The very high silt content is a major contributor to the buff colour. Limestone inclusions here are typified by the microfossil (foraminifera) in the lower left of the figure. The red-brown grain is a iron-rich clay from the weathering of a basalt outcrop (ppl, magnification x40).

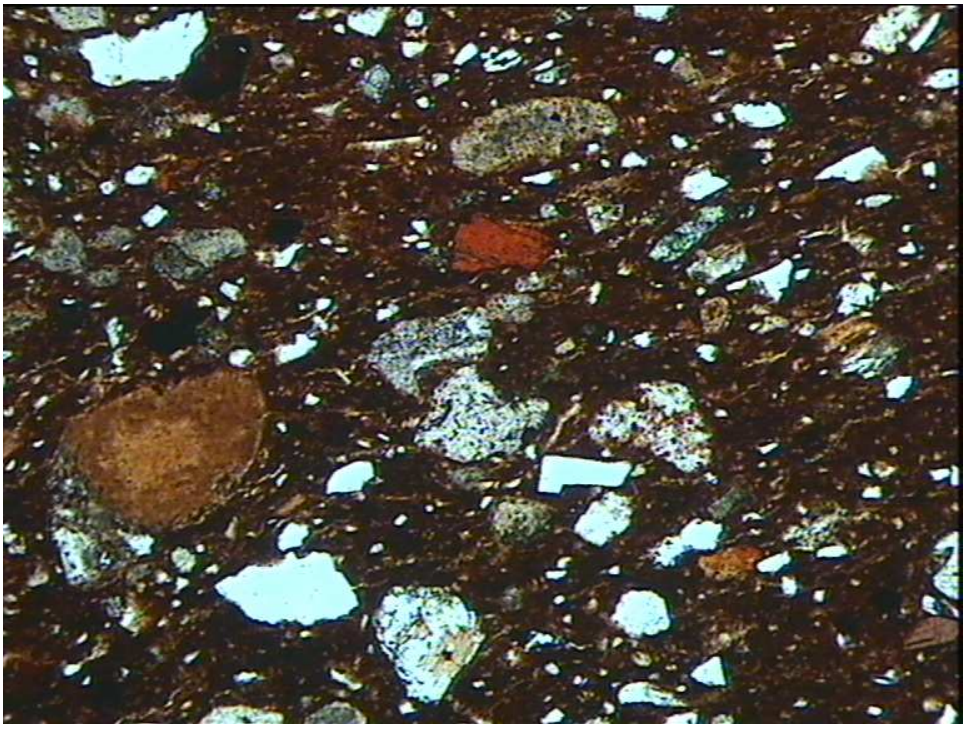

Figure 5 - ASM 7, a buff-firing fabric with limestone and volcanic inclusions. Here the there is a high inclusion:matrix ratio (ppl, magnification x40).

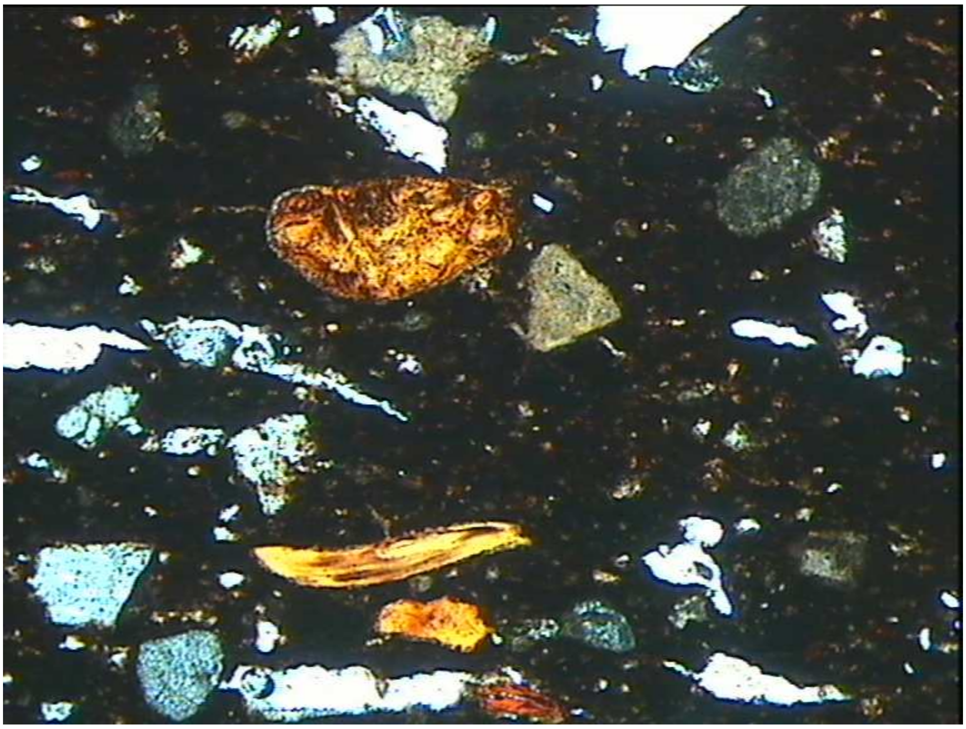

Figure 6 - ASM 5, an intermediate red- buff firing fabric. Orange-yellow grains are of goethite and iron-rich clays from basalt weathering. Limestone grains (e.g. upper right) appear greyish and speckley due to very fine microstructures resulting from thermal decomposition (ppl, magnification x40).

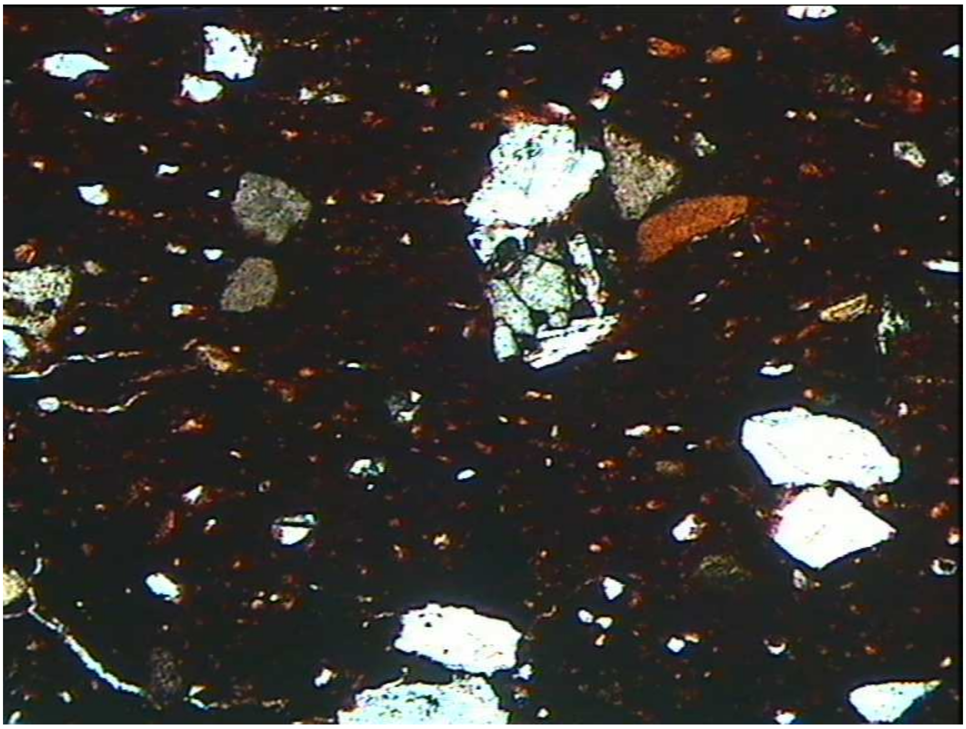

Figure 7 - D3, a red firing fabric with volcanic and limestone inclusions. The large composite grain at upper centre is a relatively fresh basalt fragment, comprising of a pale greenish clinopyroxene and colourless plagioclase feldspar. Limestone inclusions appear turbid and grey, quartz is angular and colourless. Note the relatively small amount of fine sand/silt in the matrix compared to the buff-firing ASM 3 (ppl, magnification x40).

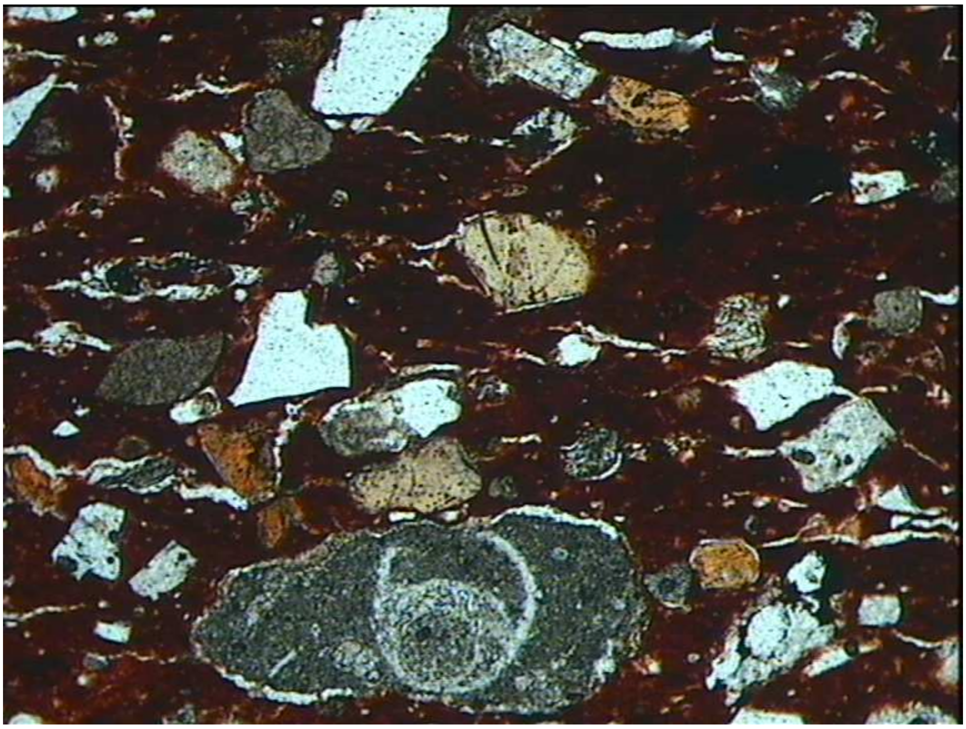

Figure 8 - ASM 10, red-firing with limestone and volcanic inclusions. These are of the same types as for D3 but are slightly coarse. Note the microfossil (foraminifera) still within the original host limestone (micrite).Again the fine sand/silt content of the matrix is relatively low (ppl, magnification x40).

4. Comments

The fundamental division within this set of Zeugma cooking wares is between the two fabric groups: quartz-tempered and limestone-volcanic types. This difference in composition reflects two very different routes to producing a 'red'-coloured cooking ware.

The quartz-tempered group is represented by a single fabric, typified by the addition of a consistently pure quartz type. This is the Type 2 fabric identified by Agnes Vokaer. Note that small differences in the amounts and sizes of the quartz temper are not considered to be a secure basis for constructing sub-fabrics. If a large enough number of these fabrics were examined the differences would be seen to be gradational.

In contrast, the limestone and volcanic inclusions of the second fabric group are all natural: no temper has been added. It is possible to suggest 2-3 fabrics on the basis of the fired colour, but there is considerable overlap here. Colour expression is dependant on a combination of clay type, inclusion type, the total inclusion proportion, the ratio of the different inclusions, inclusion size, porosity, maximum firing temperature, kiln atmosphere and length of firing. The interplay between these variables means that it is possible for a single clay type to produce a range of fired colours. Further, the type of clay deposits in use here (alluvial-colluvial) are likely to show considerable variation across short stratigraphic distances (on the centimetre scale), restricting the interpretive value of sub-fabrics.

Both red and buff fabrics combine a consistent suite of volcanic and limestone inclusions with an iron rich clay. With the red-firing fabric, the clay is not diluted by a high concentration of fine sand or silt: this allows the full expression of the oxidised red colour.

In the buff fabric, a higher proportion of fine carbonate inclusions act to dilute the colour intensity of the red clay. In addition, chemical reaction (at high temperature) between fine-grained carbonates and the iron rich clays restrict the formation of red-coloured haematite during the oxidation part of the firing cycle. This results in a buff colour. Where the amounts of fine carbonate are smaller, the dilution/reaction effect is less marked, and the result is the red-buff subfabric.

5. Glazed ware

Two of the submitted samples (P.1 and P.2) were too small for thin section analysis. Instead these glazed wares were characterised by scanning electron microscope (SEM) with semi-quantitative chemical analysis via a PGT energy dispersive spectrometer (EDS).

5.1. P.1

This is a green glazed ware with a calcareous body showing fine (<0.5mm) inclusions. The glaze is an alkali variety but is highly weathered and was not analysed further in this study. The fired body colour is buff with a slight orange hue, suggesting a calcareous variety with an oxidised iron component. This is verified by bulk chemical analysis of the body (table 2).

Table 2 - Semi-quantitative EDS analysis

	1	2	3	P1 mean	4	5	6	P2 mean
SiO_2	62.00	58.14	61.48	60.54	55.03	55.1	54.82	54.98
TiO_2	0.07	0.00	0.71	0.26	0.05	0.00	0.13	0.06
Al_2O_3	16.39	15.1	14.71	15.4	17.39	18.05	16.05	17.16
FeO	3.56	4.20	30.84	3.87	3.72	3.02	3.16	3.30
MgO	5.75	8.98	6.60	7.11	6.95	6.68	7.18	6.94
CaO	10.06	10.72	9.86	10.22	14.54	14.32	14.33	14.4
Na_2O	2.02	1.78	1.80	1.86	1.78	2.16	3.20	2.38
K_2O	1.15	1.09	1.02	1.09	0.55	0.67	1.13	0.78

This fabric was found to contain a wide variety of angular inclusions which indicate derivation from a mixed igneous and metamorphic source. These inclusions are of single and grouped minerals, and include:

- actinolite schist
- albite-epidote
- biotite
- Ca-Mg amphibole
- clinopyroxene (augite)
- ilmenite
- plagioclase (intermediate)
- potassium feldspar
- quartz
- quartz-epidote-chlorite
- serpentine
- sphene + potassium feldspar

In addition, there is also a significant component of secondary (added) material. This is a mix of workshop debris in the form of grog, waster fragments, re-cycled glaze and frit.

5.2. P.2

A slightly coarser fabric than P.1 and with a higher proportion of inclusions. The fired body is paler than P.1, suggesting a higher calcium: iron ratio, again confirmed by bulk chemical analysis (table2). Observed inclusions are:

- albite/Mg-amphibole/ilmenite composite (spillite)
- chromite
- Mg-chlorite
- clinopyroxene
- ilmenite
- plagioclase
- potassium feldspar
- quartz
- quartz-albite
- serpentine (some fused)

Again there is a significant component of added fused material. In this case there is less recycled glaze, but but more is fused serpentine.

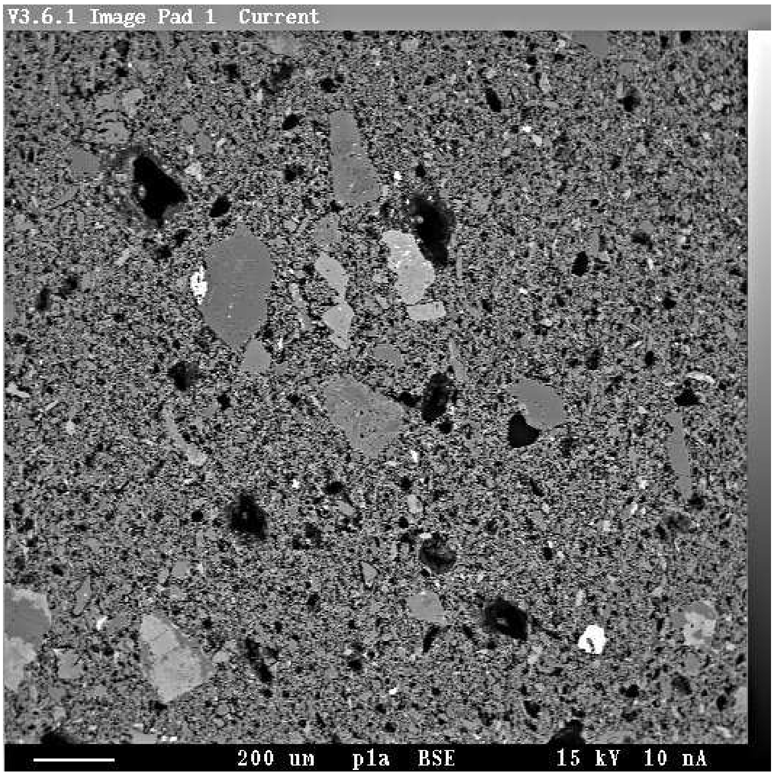

Figure 9 - P1 body showing angular inclusions in a fine-textured calcareous body. Magnification x 50 (scale bar, lower left, is 0.2mm)

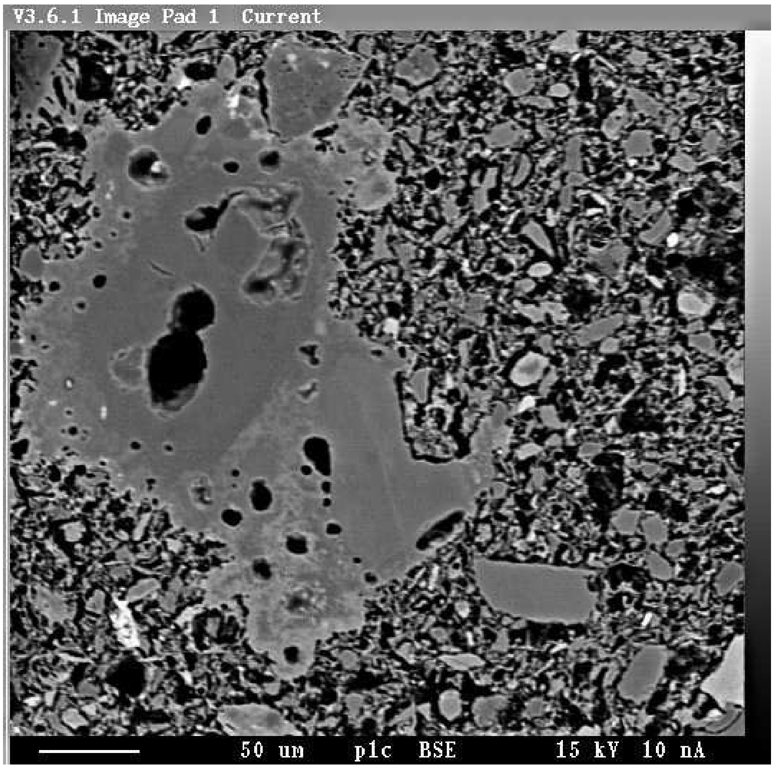

Figure 10 - P1 detail of a fused serpentine inclusion (magnification x 250).

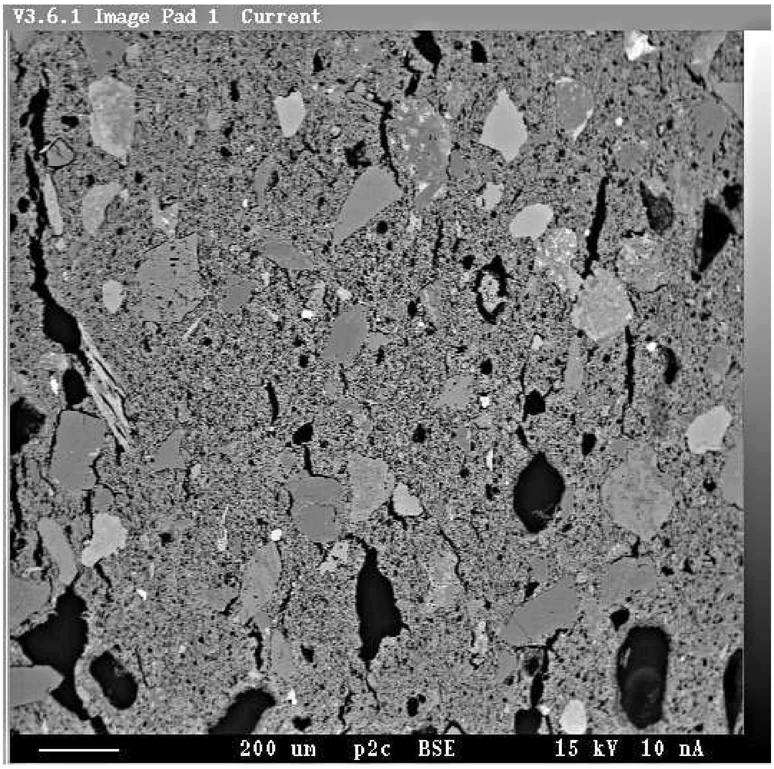

Figure 11 - P2 body - the inclusion types are similar to those of the P1 body (figure 1) but are more abundant (magnification x 50)

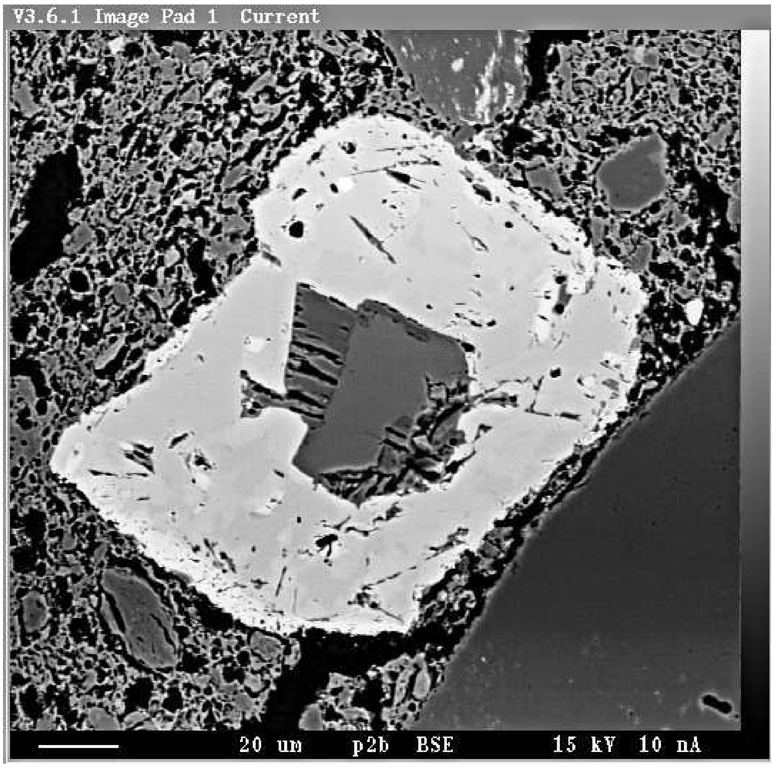

Figure 12 - P2 detail of a chromite inclusion (bright), whose presence indicates ophiolitic rocks in the source area for the body clay.

5.3. Glazed ware - comments

Both glazed wares are made from fine calcareous clays which have been tempered with natural sand and vitreous workshop waste (re-cycled glaze, fused steatite/serpentine etc). The difference in body colour relates to the proportions of calcium and iron. These are differences which are likely to occur over small distances in the natural clay deposit, and do not necesssarily imply the use of clays from different locations.