Petrographic Analysis of Table and Kitchen Wares

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TERMS OF REFERENCE

This report presents a petrographic study of table and kitchen ware pottery samples from the rescue excavations at Zeugma. Petrographic analysis of pottery employs the concept of the pottery fabric, which is defined by the sum of the constituent minerals and tempers, etc., and the overall micro structure. The fabric is the common descriptive unit, and a series of fabrics may be interpreted to provide the following information:

- The existence of fabric groups, i.e., classification of the total sherds into groups based on similar fabric elements. This provides a very valuable method of comparison, independent from that based on external characteristics (i.e., pottery form and style).
- Technological aspects such as evidence for raw material processing (e.g., the addition of temper), surface decoration, and firing conditions.
- The source of the raw materials (i.e., their provenance). This involves a comparison with the known or predicted characteristics of usable clays in the site area, or from other areas from where pottery might have been traded or imported.

Lab ref.	Fabric group	Sample ref.	Visual characteristics
ZG1	"Local" Hellenistic fine ware	Sample A	very fine — orange — oxidized
ZG1a	"Local" Hellenistic fine ware	Sample B	very fine — orange — oxidized
ZG2	Glazed fine ware	Fabric 1	very fine — greenish — oxidized — low Fe
ZG3	Glazed fine ware	Fabric 2	greenish — abundant fine sand — low Fe
ZG4	Glazed fine ware	Fabric 3	very fine — greenish — oxidized — low Fe
ZG5	Glazed fine ware	Fabric 4	very fine — greenish — not fully oxidized — low Fe
ZG6	Glazed fine ware	Fabric 5	very fine — orange — oxidized
ZG7	Buff ware	Fabric 1	orange — fine sand
ZG8	Buff ware	Fabric 2	orange — fine sand — underoxidized inner
ZG9	Buff ware	Fabric 3	fine sand — orange — oxidized throughout
ZG10	Buff ware	Fabric 4	brown — fine sand — underoxidized
ZG11	Buff ware	Fabric 5	orange — fine sand — with coarser carbonate
ZG12	Buff ware	Fabric 6	buff — fine sand (with ferruginous grains)
ZG13	Buff ware	Fabric 8	buff — fine sand (with ferruginous grains)
ZG14	Buff ware	Fabric 10	buff outer but orange core — fine sand
ZG15	Buff ware	Fabric 11 (**PT402**)	brown — fine sand — underoxidized
ZG16	Buff ware	Fabric 13	buff-orange — very fine sand
ZG17	Buff ware	Fabric 15	buff — very fine sand/silt
ZG18	Cooking ware	Fabric 1	red — fine sand — high Fe/low Ca
ZG19	Cooking ware	Fabric 2	red — fine sand — high Fe/low Ca
ZG20	Cooking ware	Fabric 4 (**PT450**)	light brown/buff — fine sand — underoxidized core
ZG21	Cooking ware	Fabric 7	orange/buff — medium sand
ZG22	Cooking ware	Fabric 8	orange — medium sand
ZG23	Cooking ware	Fabric 9	coarse sand — red outer but underoxidized core/inner
ZG24	Storage ware	Fabric 2	coarse mixed sand and carbonate–red with brown core
ZG25	Storage ware	Fabric 3	coarse mixed sand and carbonate–red with brown core
ZG26	Storage ware	Fabric 5	buff — coarse angular sand
ZG27	Reference only	Euphrates sand	Birecik: locally extracted building sand

Table 1. Zeugma table and kitchen ware sherds submitted for fabric analysis

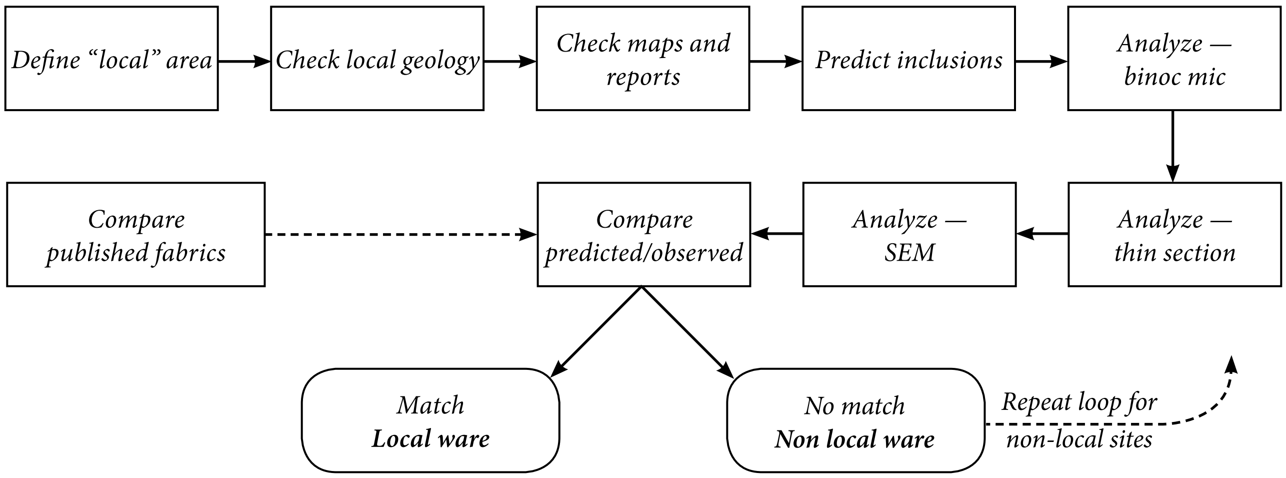

Figure 1. Outline of petrographic provenancing method.

These general aspects are reported in this chapter, in addition to answers to a series of more specific questions posed by the pottery specialist, Dr. Philip Kenrick, when the samples were submitted.

THE SAMPLES

A total of 28 samples were submitted for analysis, including a reference sample of graded building sand from a plant at Birecik that dredges its material from the Euphrates. Table 1 lists the sample details.

METHODS

All samples were initially observed using low-magnification stereo binocular microscopy in the as-received state, to record those macro-characteristics often less evident in thin section (e.g., overall color and color distribution, presence of mica at surfaces, etc.). Next, sherds were prepared as standard petrographic thin sections following impregnation with epoxy resin.

Thin sections were examined using a standard polarizing microscope (a Nikon Optiphot-2 model) to record the nature of the inclusions and clay matrix, i.e., the fabric of the sherd.

Compositionally these fabrics are complex, containing a relatively large suite of mineral and other inclusions. This is consistent with the highly varied geology of southeast Turkey, the catchment of the Euphrates headwaters. The petrography is further complicated due to

- natural weathering of many of the minerals, obscuring some of their diagnostic optical properties;
- transformation of many minerals due to firing;
- the very fine grain size.

Clearly, discriminating between locally produced pottery and that which may have been traded demands a comprehensive understanding of the compositional characteristics of the local clay. Towards this end, thin-section analysis of the Birecik sand reference sample was supplemented by scanning electron microscopy (SEM). This technique combines very high magnification with the ability to perform discrete quantitative chemical analysis on individual minerals, to assist the identification of problematic inclusions. The instrument used in this study was a Cameca SU30 Semprobe fitted with a PGT energy dispersive analyzer (EDA). Typical operating conditions for quantitative EDA were 15 kV, 10 nA, 100 second count time.

THE NATURE OF THE LOCAL POTTERY CLAYS AT ZEUGMA

Ideally, pottery provenance studies should involve the sampling of potential clay deposits at the site, for petrographic characterization and to determine the degree of stratigraphic and lateral variation. Unfortunately, there was no opportunity for such fieldwork in this case, and the expected nature of the locally available clay had to be modeled indirectly. This is commonly the case for many provenance studies, as sites are often not accessible (or even known). In these cases, the success of indirect modeling is very dependant on the quality of the available geological and soil maps and reports of the area. For Zeugma the degree of geological coverage is moderately good.

Figure 1 shows the general scheme adopted for identifying the possible provenance for these wares. A review of the local geology of Zeugma and of the Euphrates headwaters allows a prediction to be made of the types of inclusions likely to be present in Zeugma clays. The predicted mineralogy is then tested against the observations made on the reference sand samples and the inclusion list is

	Sedimentary	Igneous	Metamorphic
Rock type	Conglomerates, sandstones, siltstones, mudstones, marl (including gypsum-bearing), carbonates, chert.	Acid, intermediate, basic, and ultrabasic intrusives (granite, granodiorite, diorite, gabbro, etc.), extrusives (rhyolite, dacite, andesite, basalt, etc.), and volcanoclastics (tuff, tuffite).	Medium- and low-grade regional metamorphic rocks of amphibolite and greenschist facies. Dynamometamorphic rocks (i.e., crushed, sheared fabrics) with abundant vein quartz.
Main minerals and rock debris	Quartz, potassium feldspar, plagioclase feldspar, muscovite, chert, calcite, fossil fragments, Foraminifera, etc.	Quartz, potassium feldspar, plagioclase, feldspar, muscovite, biotite, amphiboles, clinopyroxene, olivine, volcanic glass, groundmass.	Quartz, epidote, albite, chlorite, biotite, muscovite, amphibole (Ca+Mg), serpentine, zeolites.
Minor minerals	Amphibole, pyroxene, olivine, rutile, zircon.	Chromite, magnetite, ilmenite, sphene, zircon, tourmaline, rutile, anatase.	Kyanite, garnet, stauralite, chloritoid, talc.

Table 2. The geology of the Euphrates headwaters.

modified accordingly. A final modification may be made to accommodate clay/inclusion details published in archaeological site or pottery reports for the region, particularly those employing a similar or overlapping methodology. However, a main difficulty when comparing fabrics against those previously published is the petrographic detail in the latter. Where this is comprehensive, then a useful comparison can be made. More commonly, however, published petrographic descriptions are brief, often designed to summarize rather than fully characterize the pottery. Here it is often very difficult to make comparisons with the fabrics being studied.

At the end of this procedure we have a good working list of inclusions that can be considered to be characteristic of the local clay and, from our review of the sedimentology and climate of the region, an understanding of how much variation might be expected on a local and regional scale.

Predicted Euphrates Clay Mineralogy at Zeugma

There are two sources for predicting the expected clay characteristics: geological maps and published reports. In this study we are interested in a relatively large area upstream of Zeugma. This is because sediments being deposited at Zeugma are mainly derived from the headwaters of the Euphrates and closely reflect the geology of southeast Turkey. These inherited sediment characteristics persist the full length of the Euphrates but become increasingly modified by sediment coming in from local tributaries and the eroding river banks. At Zeugma the local geology is dominated by limestones, with lesser interbedded sandstones. These variably dilute the main Euphrates sediment by adding mainly limestone (including fossil debris) and sand grains. The magnitude of this local modification increases away from the main Euphrates channel, being most marked at the floodplain margins.[1]

By any standard, the geology of southeast Turkey is very complex, with a wide range of rock types occurring in a relatively small geographical area. Further, many of the rock units have an overall east-west trend, and as the Euphrates flows north-south over a large part of its upper course it erodes a relatively large range of rock types. The result is a mineralogically complex sediment load. Table 2 summarizes the main rock types within the Euphrates catchment and predicts the minerals likely to be liberated by their erosion.

Observed Euphrates (Clay) Mineralogy at Zeugma

The typical inclusions that might be expected in clay made from Zeugma can be approximated by analysis of a sand fraction taken from the active channel at Birecik. While there will be some differences, most of the sand inclusions will also be those found in near-channel clays. Table 3 identifies the inclusions found in this reference sand.

A comparison of table 2 with table 3 shows that there is a relatively good agreement between the predicted and observed inclusion types. The main differences result from the fact that the predicted inclusion list is based mainly on material being eroded in the Euphrates headwaters and does not account for sediment from local tributaries and wadis. This latter input is volumetrically less significant in the center of the floodplain but becomes more important towards the margins. The local geology at Zeugma is dominated by limestones with interbedded sandstones. These would be expected to contribute mainly carbonate, fossil debris, and sand grains, all of which are observed in the Birecik sand.

Having verified the predicted characteristics of the local clay at Zeugma, we can now confidently recognize nonlocal fabrics on the basis of their anomalous inclusions.

Aegerine-augite	Colorless amphibole	Phrenite	Serpentine
Allanite	Clinopyroxene	Plagioclase	Sphene
Apatite	Dacite	Polycrystalline quartz	Titanaugite
Basalt	Epidote	Phyllite	Titanomagnetite
Basaltic glass	Fe-alteration	Magnetite	Tourmaline
Biosparite	Foraminifera	Micrite	Trachyte
Bioclasts	Garnet	Monocrystalline quartz	Tremolite
Biotite	Granite	Muscovite	Vein quartz
Calcite	Granodiorite	Myrmekite	Zircon
Chert	Hornblende	Orthoclase	
Chlorite	Ilmenite	Rutile	
Chromite	Potassium feldspar	Rhyolite	

Table 3. Inclusions observed in Euphrates sand from Birecik.

RESULTS

This program of petrographic analysis addresses several queries relating to fabric groups for the Zeugma table and kitchen wares, these groups having been established in the field by the pottery specialist. Accordingly, the findings of this analysis are presented here as replies to these specific questions.

"Local" Hellenistic Fine Ware

Question 1: This is presumed to be local (or at least regional) because of its frequency and because of the resemblance of the clay to that of the most common buff ware fabric. Is this justified? Two samples are submitted: Sample A has no visible inclusions; B contains some very fine white specks and mica. Are these merely variants of the same clay, or are there significant differences? **Responses:** Sample A: a comparison of the following list of mineral inclusions with table 2 verifies that this is a local fabric. These are chert, basalt, zoned plagioclase, monocrystalline quartz, polycrystalline quartz, carbonate, microgranite, orthoclase, muscovite, biotite, altered basalt (ferruginous alteration products), serpentine, augite, and epidote. Inclusions are typically angular in shape, are of very fine grain size (estimated mean 0.15 mm, max. 0.75 mm), and represent 10–15 percent of the total sherd volume.

Sample B: this sample has a very similar suite of inclusions to sample A, but there are some small differences, i.e.:

- B has a significant amount of Ca-amphiboles; these are absent/very rare in A.
- B has a much higher proportion of total inclusions (estimated at 25–30 percent of total sherd volume). The inclusion size and shape characteristics are the same as in sample A.
- B has more fine-grained carbonate in the matrix (although the latter is likely to be less conspicuous in the higher fired sample A).

Clearly, these samples are closely related, as both contain the typical Euphrates mineralogy. Both are micaceous but this is more obvious with sample B, which is more inclusionrich. The lighter color of sample B is mainly due to dilution by a high proportion of light-colored carbonate. However, the presence of significant amounts of amphibole in sample B does suggest the use of slightly different clays. The shape of these amphibole grains (euhedral) suggests that they are derived from volcanic material, either (andesitic) lava flows or ash. The interpretation suggested here is that these clays are derived from different floodplain terraces, one of which (B) was forming at a time when volcanic activity was introducing ash or flows into the Euphrates catchment. Unfortunately the existing geological literature does not record compositional differences between the Euphrates terraces at this resolution. Table 4 summarizes the similarities and differences between the relevant fabrics.

Glazed Fine Wares

Question 2: Are fabrics 1 ("Parthian") and 3 related or distinct?* **Response:** These are quite different. Fabric 1 is very fine-grained, has no sand, and has abundant carbonized plant remains. Fabric 3 is higher-fired but originally would have contained a significant amount of rhombic (soil) carbonate plus small amounts of granitic sand. These fabrics could be lateral floodplain equivalents, with fabric 1 clays being derived from near the main Euphrates channel, fabric 3 at the flood plain margin.

Question 3: Is fabric 3 related to Buff fabrics 1–3? **Response:** Yes. Fabric 3 is characterized by a fairly typical Euphrates mineral/clastic assemblage including quartz, potassium feldspar, plagioclase feldspar, chert, basalt, mica-schist, quartz-epidote, carbonates, and ferruginous weath-

* The samples were chosen and the questions formulated before it was appreciated that not all of the glazed wares are Islamic in date. — PMK

	Local Hellenistic fine (A)	Local Hellenistic fine (B)
Buff 1	Similar inclusions but Buff 1 is a much coarser fabric (mean grain size 0.5 mm compared to 0.15 mm for sample A).	Differs in grain size, as with sample A. Also sample B has significant amphibole content (absent from Buff 1).
Buff 2	Different fabrics. Both have local Euphrates clay inclusions but differ significantly in relative proportions, total amount of all inclusions (Buff 2 > sample A), and grain size (Buff 2 > sample A).	Different fabrics (as for sample A).
Buff 3	Essentially the same inclusions but Buff 3 is coarser (mean 0.5 mm; sample A mean 0.15 mm) and has a higher overall total of inclusions (estimated at 40% of sherd volume). Also carbonate-rich.	Different fabrics. Same as for sample A, but Buff 3 also lacks the euhedral amphibole (hornblende) that is a feature of sample B.
Buff 13	Near-identical fabrics.	Differs only by the amphibole content of sample B.

Table 4. Comparison of "local" Hellenistic fine ware and plain buff fabrics.

ering products (mainly after basic igneous rocks). Buff 1 is similar but has noticeably more quartz and feldspars, suggesting a greater input from acid igneous rocks (granite, etc.) Buff 2 has similar inclusions but these are present in different proportions. It is also more micaceous and has rounded carbonate grains. Buff 3 is similar to Islamic glazed fabric 3.

Question 4: Is fabric 2 ("Parthian") related to buff fabrics 6, 8, or 10? **Response:** No. Fabric 2 is tempered with tectonized[2] quartz and quartzite, chert, schist, and basalt; it has no limestone. Buff 6 has a very different clay matrix that is rich in foraminifera and has a lower sand content with little or no basaltic or secondary ferruginous aggregates. Buff 8 is different, again having a foraminifera-rich matrix, significant soil carbonate, and a lower siliclastic input. Buff 10 differs by having a high-calcareous matrix and fewer inclusions, which are also finer-grained.

Question 5: What are the characteristics/possible sources of fabrics 4 and 5? **Response:** Fabric 4 is a very fine-grained calcareous fabric with a pale green fired body color. Inclusions are estimated at 15 percent of the total volume and have a maximum grain size of 0.6 mm. Inclusions are mainly (>80 percent) carbonate, being a mix of micrite, foraminifera, and thin-walled shells. Most carbonate grains have thermally decomposed during the high firing. Other inclusions comprise small amounts of quartz with rare potassium and plagioclase feldspars. This is a naturally fine-grained clay.

Fabric 5 is an orange-brown fabric with abundant natural inclusions (mean grain size 0.6 mm). Inclusions are typical of those expected from the Euphrates sediments and include: quartz (mono- and polycrystalline), potassium feldspar, plagioclase feldspar, clinopyroxene, hornblende, biotite, trachytic basalt, basalt, epidote, rhyolite, muscovite schist, serpentine, and chromite (rare).

Plain Buff Wares

Question 6: Buff 1–3 are presumed to be local. Are they distinct or merely gradational? **Response:** Gradational. Essentially these share the same suite of mineral and rock inclusions, which is consistent with a Euphrates source at Zeugma. Buff 1 and 3 are similar, having a reddish-firing clay suggesting proximity either to the main river channel or an abandoned cut-off. Buff 2 is not red-firing, suggesting a higher Ca:Fe ratio, further born out by its more frequent (degraded) carbonate grains. Buff 2 could represent clay from the floodplain margin, being diluted by carbonate from groundwater and a clastic input from adjacent limestone formations.

Question 7: Buff 1 and 2 should correspond to the (local?) amphora fabrics 1 and 2: Is this so? **Response:** To answer this it is necessary to compare them with individual members of amphora fabric groups 1 and 2, as both were found to show considerable variations (summarized in tables 5 and 6, respectively). The results of this comparison are shown in table 7.

Lab ref.	I.D.	Initial fabric group	Revised fabric group
ZG28	2010.7	**AM93** fabric 1	fabric 1
ZG29	2012.2	**AM125** fabric 1	fabric 1 fine
ZG30	2012.2	**AM125** fabric 1	fabric 1 fine
ZG31	2012.3	**AM126** fabric 1	fabric 1
ZG32	2039.8	**PT387** fabric 1	fabric 1

Table 5. Amphora fabric 1 members.

Lab ref.	I.D.	Initial fabric group	Revised fabric group
ZG41	2039.25	**AM171** fabric 2	fabric 2: redder with abundant carbonate
ZG42	2260.60	**AM219** fabric 2	fabric 1
ZG43	2080.16	**AM183** fabric 2	separate fabric: dacite + schist with abundant carbonate
ZG44	2080.1	**AM197** fabric 2	fabric 1

Table 6. Amphora fabric 2 members.

Amphora fabric Fabric 1	*Plain buff ware* Buff 1
ZG28	Similar except that Buff 1 has a lower total inclusion content and fewer fossil fragments/ foraminifera
ZG29	Not similar: Buff 1 lacks a significant silt content, has coarser sand, and has more basalt-derived inclusions
ZG30	As for ZG29
ZG31	Similar except amphora has more silt/fine sand and more fine-grained carbonate in the matrix
ZG32	As for ZG31
Fabric 2	**Buff 2**
ZG41	Not similar: Buff 2 has more acid igneous inclusions (granite/dacite), has less basalt, and has more carbonate grains including rounded foraminifera/gastropod infills
ZG42	(Reassigned to fabric 1)
ZG43	Very similar fabrics
ZG44	(Reassigned to fabric 1)

Table 7. Comparison of plain buff fabrics with local amphora fabrics 1 and 2.

Buff 1 may therefore be said to be similar to the coarser subgroup of amphora fabric 1, whereas Buff 2 corresponds to only one member of amphora fabric 2 (as visually defined).

Question 8: Buff 4 is coarser (more sandy) in appearance than Buff 1–3. Is this a different clay? **Response:** No. Although more gritty, this is essentially the same clay as the Buff 1–3 series. It has slightly more limestone and chert but shares most of its inclusion types with Buff 1–3.

Question 9: What are the characteristics of Buff 5? **Response:** Buff 5 has a pale brown fabric with conspicuous inclusions of up to 2.5 mm maximum grain size (mean 0.5 mm). Inclusions are mainly (>95 percent) those derived from the erosion of a recent fossiliferous limestone and comprise micrite, foraminifera, and thin-walled shells. Other inclusions are mainly basalt (ophitic) and corresponding clinopyroxene and plagioclase feldspar. Quartz is present as a minor component. This fabric is derived from a clay formed in a limestone-dominated area but with basaltic outcrops in the catchment. There are none of the typical Euphrates-channel-type inclusions.

Question 10: Buff 6 (mortaria) is not far removed in appearance from Buff 8. Are they the same? **Response:** No. There are some similarities, mainly that both are made from very fine-grained calcareous clay with conspicuous foraminifera, but there are important differences in their inclusions. Buff 6 inclusions are mainly derived from acid to intermediate igneous rocks (dacite, granodiorite) and chert with little or no basic igneous material. Buff 8 has acid, igneous-derived, and chert, but also basic igneous types, degraded limestone, and a higher content of ferruginous alteration products (from weathered basalt/gabbro).

Question 11: How does Buff 6 relate to the Syrian amphora fabric 13? **Response:** First, amphora fabric 13 shows sufficient variation to warrant subdivision into two separate subfabrics as shown in table 8. Buff 6 and amphora 13 fabrics are compared in table 9.

Question 12: Is Buff 8 the same as the Syrian amphora 13? **Response:** Confirmed. All the amphora fabric 13 members are very similar to Buff 8, allowing for differences in firing, proportions of inclusions, etc. Overall, Buff 8 is more closely matched to the amphora fabric 13 sherds than Buff 6. The latter lacks the colorless amphibole that characterizes Buff 8 and amphora fabric 13.

Question 13: Buff 10 looks like a finer version of Buff 8: Is this so? **Response:** No. The inclusions are similar but the clay bodies are different. Buff 8 has abundant foraminifera whereas these are rare in Buff 10 (allowing for loss with the higher firing of Buff 10). Buff 10 also has a more developed red color, due to a relatively high concentration of very fine reddish ferruginous material (from weathered basalt/ gabbro).

Lab ref.	I.D.	Initial fabric group	Revised fabric group
ZG51	2010.6	**AM110** fabric 13	fabric 13
ZG52	2080.4	**AM194** fabric 13	fabric 13
ZG53	2154.1	—— fabric 13	fabric 13, coarser variety
ZG54	5034.1	**AM264** fabric 13	fabric 13
ZG55	7026.1	**AM295** fabric 13	separate fabric, schistose
ZG56	7036.1	**AM296** fabric 13	separate fabric, granodioritic
ZG57	12012.59	—— fabric 13	fabric 13

Table 8. Amphora fabric 13 members.

Amphora fabric 13	Plain buff fabric 6
ZG51	Similar fabrics; Syrian 13 also has a very calcareous matrix that is rich in foraminifera. Notably there is very little in the way of fine siliclastic material but a relatively well sorted medium sand. Arguably this could represent tempering, but natural sand incursion into a lagoonal environment is not ruled out.
ZG52	Similar fabrics although Syrian 13 fabric has no/little tuff and has more altered ferruginous material (laterite — basalt derived?).
ZG53	Similar in terms of inclusions and the calcareous nature of the clay. This Syrian 13 fabric has intraclasts of laminated calcareous clay.
ZG54	Less similar on account of the much higher proportion of ferruginous material (altered basalt) shown by Syrian 13. Also has no tuff.
ZG55	Same fabrics.
ZG56	Very similar fabrics but Syrian 13 has significantly more carbonate grains and foraminifera.
ZG57	Similar fabrics (Syrian 13 higher fired).

Table 9. Comparison of plain buff fabric 6 with Syrian amphora fabric 13.

Question 14: PT402 (Buff 11) is an isolated example of a mortarium with distinctive black grits: any comments? **Response:** Most of the inclusions in this fabric have been derived from a highly weathered basalt/gabbro. Here, iron released on weathering has reprecipitated to form a black colored cement or coating on grains. This results in the dark color of the matrix. A variety of basaltic textures are observed, including serpentinized and vesicular types. Other typical Euphrates minerals are present but do not significantly dilute the altered basaltic signature. This implies use of a clay either from a Euphrates tributary draining a basalt area, or immediately downstream of where the Euphrates incises a basaltic outcrop.

Question 15: Buff 13 is a fine buff ware. Is it related to Buff 1–3 or to "local" Hellenistic fine ware? **Response:** Although they have similar inclusions, Buff 1 and Buff 13 are different, as the latter has a significantly higher proportion of angular fine material. Buff 13 and Buff 2 also differ, with Buff 2 having much more mica and epidote (derived from mica-schist). Buff 13 differs from Buff 3 in having significantly less limestone — although it shares most of the other inclusions and is probably related laterally on the flood plain. Finally, Buff 13 is almost identical to the Hellenistic fine A sample (see question 1); it has some similarities to Hellenistic fine B, which, however, has much more fine-grained limestone/carbonate.

Question 16: Is Buff 15 related to any of the preceding? **Response:** This fabric has a very high proportion of fines as well as the typical Euphrates mineralogy represented in the coarser fraction. This could possibly be a finer (distal[3]) variant of Buff 11 (**PT402**). There may be a reworked tuff component.

Augite	Micrite
Basalt	Microdirite
Biotite	Monocrystalline quartz
Caliche	Muscovite
Chromite	Plagioclase
Colorless Amphibole	Polycrystalline quartz
Epidote	Potassium feldspar
Fe-alteration	Serpentine
Hornblende	Titanaugite
Mica Schist	Trachy-basalt

Table 10. Inclusions observed in Cooking 1.

Characterization of Cooking Wares

Cooking 1

Question 17: This is a red fabric with an extensive suite of inclusions (table 10). A comparison with table 3 suggests a strong similarity with the Euphrates sediment samples at Zeugma. However, Cooking 1 shows some subtle but significant differences, i.e.:

- Cooking 1 grains are very angular;
- plagioclase feldspar are not conspicuously zoned;
- muscovite laths are commonly kinked (suggesting a metamorphic/tectonized history);
- there is a relatively high concentration of basalt and derived minerals.

Pinpointing a possible provenance for this material is difficult. The overlap with many of the Euphrates sand minerals suggests it could be derived from the same catchment, i.e., southeastern Turkey. The listed differences could be consistent with Euphrates clay upstream from Zeugma, nearer to the major east-west faults and outcrops of volcanics. One problem here is that basalts from this area tend to contain the distinctive titanaugite clinopyroxene. Only a single occurrence of titanaugite was noted for Cooking 1, despite other indicators that the clay must have been formed relatively close to a basaltic outcrop.[4]

Cooking 2

Question 18: This fabric is based on a red clay that has been tempered with a very pure quartz sand. An estimated 98 percent of all sand grains are mono-crystalline and are essentially strain-free (with extinction complete in under five degrees of rotation). The sand grains are moderately well sorted with a subangular to subrounded morphology. Many are subhedral (i.e., showing partial crystal faces), which, with the mono-crystalline and strain-free characteristics, suggests derivation either as quartz phenocrysts from acid volcanics (e.g. rhyolite/rhyolitic tuff) or from vein quartz.

Of these two possibilities vein quartz is favored as, unlike a rhyolitic source, this would not introduce other siliceous material. This is a compositionally very mature sand temper and is undiluted by alluvial material or carbonate, suggesting a short transport history, possibly a residual material.

The deep red color of the clay indicates that this is iron-rich. Possible sources here are residual clays developed on limestone (terra rossa) or those derived from the weathering of basalt. In the latter case this weathering would have to be very complete and the clay subsequently redeposited to remove all coarser material and give the observed very clean fabric. The use of a residual terra rossa clay, being free from coarse impurities, presents a simpler scenario and is favored in this interpretation.

Accepting the above, Cooking 2 could have been made at a site where limestone, possibly with quartz veining, has undergone extensive weathering. Existing geological reports and maps do not have sufficient resolution to identify possible sites from within the extensive outcrops of Mesozoic limestone in the area. Archaeological input is required at this stage to narrow down possible locations.

Cooking 4

Question 19: This is an obviously non-Euphrates alluvium fabric dominated by andesitic volcanic material including ash and pumice. This fabric exhibits a simple mineralogy of plagioclase feldspar (andesine), hornblende, biotite, and very rare quartz. The quartz shows an embayed texture and is associated with a glassy matrix, indicating that it is also derived from a volcanic source.

All of these inclusions reconstruct to give an intermediate volcanic rock type, andesite. There are no mineral inclusions that are foreign to andesite and that would imply some degree of sediment mixing. This single rock parentage, and the very angular shape of the inclusions, indicates that this clay has not been transported by an alluvial system but has formed as a residual deposit on the andesitic parent. The clay matrix has derived from the chemical weathering of the andesite and has become naturally mixed with volcanic ash (andesitic) during down-slope movement. Such an environment would be found on the lower slopes of a recent volcanic cone. The lack of chemical alteration of the hornblende and plagioclase suggests a relatively young age for the parent andesitic ash.

Numerous small andesitic cones and flows occur within the limestone country within 30 km east and west of Zeugma and also downstream in the Euphrates Valley to the Syria-Iraq border at Deir-az-Za. All of these are young (Neogene) volcanic features that petrographically are likely to be very similar. Outside of the Euphrates Valley, similar andesitic outcrops are found westward to the Syrian-Turkish coastline and are common across much of the eastern Mediterranean. It is not possible to present a unique provenance for this fabric unless archaeological criteria can be invoked to reduce the field.

Cooking 7

Question 20: This fabric appears initially to have many of the Euphrates alluvium minerals/lithologies sampled at Birecik, but is now seen to have some significant differences. Inclusions of fine-grained limestone, chert, basalt, quartz (mono- and polycrystalline), orthoclase, plagioclase, hornblende, augite, and serpentine are similar to those found in Euphrates alluvium (see table 3). However, there is an additional suite of inclusions not noted in the reference Euphrates sand or the local fabrics. These include epidiorite, psammite, quartz-epidote, zoisite, mica-schist, tectonized granite, anthophyllite, and tectonized/sheared quartz vein material. Together, these inclusions indicate the incorporation of a significant amount of metamorphic material. This includes regionally metamorphosed material of greenschist and amphibolite facies, as well as dynamo-metamorphic material associated with shear zones and major faults. This amount of metamorphic material is not seen in local Euphrates sediments but a close match is seen with the one fabric 8 amphora (**ZW50**). Two possible sources are considered that should have metamorphic components:

THE COASTAL STRIP ALONG THE TURKISH-SYRIAN BORDER: Here the Baer-Bassit ophiolite and associated metamorphic sole could furnish the observed inclusions. Material moving southwards from this outcrop mixes with north-moving Nile sediment, which could introduce the other observed inclusions. However, there are several difficulties with this source, such as:

- the amount of metamorphic rocks is volumetrically small;
- serpentine and ultrabasic igneous inclusions should be more abundant;
- these metamorphics are of a higher grade than observed in Cooking 7 and include exotics such as skarns;
- crushed fabrics should be limited.

THE METAMORPHIC BELT EXTENDING SOUTHEAST FROM MALATYA, TURKEY: This extensive metamorphic zone is intersected by the Euphrates headwaters about 100 km upstream of Zeugma. Clays immediately south of this area should show significant amounts of metamorphic materials of the types observed, in addition to the typical Euphrates mineralogy. From a purely compositional viewpoint, this is the better of the two sources for this fabric.[5]

Cooking 8

Question 21: This fabric is characterized by abundant rounded limestone, and more angular quartz, orthoclase, euhedral plagioclase, quartzite, quartz-epidote, chert, granodiorite, volcanic tuff (minor), schist, and various tectonized materials suggesting a significant input from a faulted metamorphic basement. Many of these inclusions are typical of Euphrates sediments but there are some notable absences. Compared to the reference sand sampled at Birecik, Cooking 8 has almost no basalt or andesite/dacite-derived material and has no serpentine.

Cooking 9

Question 22: The inclusions in this fabric are dominated by olivine basalt and gabbroic temper, accounting for an estimated 95 percent of the total inclusion population. Others comprise rounded grains of soil carbonate (caliche), angular mono-crystalline quartz, and fine-grained ferruginous material derived from basalt weathering. These inclusions indicate a clay source very near to a basalt/gabbro outcrop as there is minimal dilution by nonbasaltic material.

In terms of a possible source of olivine basalt, there are several contenders (i.e., from a strictly geological viewpoint).[6] Outcrops of olivine basalt occur in several regions near Zeugma. These are:

1. Turkish outcrops in the Euphrates headwaters, e.g., the Elaziğ area (Malatya) and the Bitlis massif and its westward continuation
2. Turkish outcrops in the Karasu Valley north of Antioch
3. Turkish outcrops along a major fault running northeast-southwest just to the north of Adana
4. Along the Golan Heights of Israel and Syria
5. Along the central valley of Lebanon
6. The Badia platform of Jordan

As stated previously, a robust provenance identification would really require a geochemical comparison between the pottery temper of Cooking 9 and these sources. However we can evaluate each of these on the basis of their petrography and their geological settings. Olivine basalts occur in the Euphrates headwaters between Malatya and the Bitlis massif.[7] The Malatya olivine basalts are described as containing the mineral titanaugite, a distinctive pyroxene showing a purplish color in thin section. Small amounts of this mineral are recorded in the Zeugma reference sand and some local fabrics, which is to be expected given that the Euphrates headwater tributaries traverse this region. Titanaugite, however, is not seen in Cooking 9. Further, the Malatya olivine basalts are recorded as being closely associated with other volcanic rocks (andesites and dacites): again, these occur in the Zeugma sand but are absent from Cooking 9.

Olivine basalts of the Bitlis massif are also characterized by titanaugite.[8] This area has also been subjected to metamorphism and fracturing associated with major faulting. However no metamorphic or crushed material is seen associated with the olivine basalt fragments in Cooking 9. Turkish sources north of Zeugma are not considered to be likely candidates.

Olivine basalts outcrop in the Karasu Valley north of Antioch (Hatay).[9] Here they are associated with two other related volcanic rocks, quartz tholeiite and olivine tholeiite. These are recorded as showing a variable replacement of olivine by iddingsite, a feature seen in Cooking 9. Similarly titanaugite is not recorded (calcic augite is the characteristic clinopyroxene), making the Karasu Valley a possible source of Cooking 9–type fabrics.

In the Iskenderun Gulf region (east Ceyhan) two olivine-bearing volcanic rock types are represented, alkali olivine basalts and basanites.[10] However, although these have the essential mineralogy seen in Cooking 9 (i.e., olivine, augite, and plagioclase) they are not a good match when compared texturally (even allowing for variations expected from different cooling histories within the basalt flow). These volcanics are described in the field as being highly vesicular, with olivine phenocrysts often showing signs of partial re-absorption and Cr-spinel and titanomagnetite inclusions in olivines. As these features are absent from Cooking 9, this region is not considered to be a likely source.

Syrian outcrops of olivine basalt are seen in the Tartous area (Dahr-Safra plateau) as localized outcrops of olivine-bearing high-aluminous basalt.[11] However, again there are significant petrographic differences between these and the Cooking 9 basalt inclusions. Here the olivine crystals have been derived from earlier volcanics and as such are extensively corroded or replaced by secondary minerals including serpentine. These basalts (and similar outcrops east of Damascus) are not considered as likely sources of the Cooking 9 clay.

The Golan Heights have Pleistocene volcanics consisting of volcanic flows of olivine-bearing basalts.[12] Like the Cooking 9 fabric, these basalts are relatively fresh and do not contain distinctive minerals such as titanaugite. Geologically these would be capable of yielding clays similar to those comprising Cooking 9, but it is questionable whether residual clays would develop sufficiently, given the elevated and arid location.

Finally, central Lebanon has significant deposits of olivine basalt, with flows ranging from 5 to 20 m thick.[13] A wide variety of textures are present, but olivine is usually fresh and clinopyroxenes are colorless in thin section. On these Cooking 9 could be derived from these basalts; again, field sampling and geochemistry would be required to further test this.

To conclude, on geological and locational grounds the Karasu Valley north of Antioch is the best regional contender for the provenance for Cooking 9. This match is made on fairly simple petrographic criteria and would require further geochemistry and field sampling to verify it.

Comparison of Zeugma Cooking Ware Fabrics with Syrian "Brittle Wares"

Question 23: How do these compare? **Response:** A brief comparison is made between these Zeugma cooking wares and published "brittle ware" fabrics from Syria. This comparison is based on a single source, Bartl et al. 1995. More recent fabric work on Syrian "brittle wares" is nearing completion but is as yet unpublished (Agnès Vokaer, personal communication).

Following a geochemical and thin-section study of 54 North Syrian brittle wares, Bartl, Schneider, and Bohme identified three major groups plus the suggestion of two further groups. These are clearly defined by both chemical and petrographic criteria, although the petrographic summaries given are very brief.

GROUP 1: Pottery is made of "a non-calcareous clay with a high amount of equally-sized fine-grained rounded to subrounded quartz" — a perfect match to Zeugma Cooking 2.
GROUP 2: These fabrics are characterized by the use of a calcareous clay and inclusions of "medium to coarse grained fragments of a volcanic rock, possibly from a trachytic tuff." This description is perhaps rather general, but from the figure it can be estimated that tuff represents more than 75 percent of the total temper. Group 2 sherds seemed to occur only in the later periods and were distributed mainly in the Habur valley. The one Zeugma sherd with this amount of tuff is **PT450**, but here the temper is 100 percent andesitic tuff (ash) and shows a very different size range.

GROUP 3: Fabrics have "a high amount of fine to very fine grained inclusions of various minerals and rock fragments such as quartz, feldspars, micas, serpentine, volcanic rock, chert, limestone, marble and the remains of fossils."

These minerals are clearly similar to those observed in the Birecik reference sand (table 3) and the majority of the Zeugma buff wares. This mineral assemblage identifies the clays as being derived from the same general catchment area as the Euphrates sediments (i.e., southeastern Turkey) but without further detail on the specific minerals/rock inclusions it is not possible to restrict the provenance to the Euphrates Valley.

GROUP 4: This is represented by a single member whose coarse inclusions are described as being from a "crushed coarse-grained basaltic rock." This is unfortunately far too general a description to be diagnostic. If the basaltic rock is an olivine basalt then there are obvious close similarities with Zeugma Cooking 9, if not then there is no match with the Zeugma cooking wares.

GROUP 5: Again represented by only a single member, here briefly described as being from "an altered gabbro as is typical for ophiolitic rocks from a greenstone belt." A possible match here would be with Zeugma Storage 2 which is tempered with altered gabbro and associated basic rocks. Again more petrographic detail for the Group 5 fabric would be required to verify this match.

Characterization of Storage Wares

Storage 2

Question 24: This fabric contains inclusions derived from basic igneous rock, many of which have been extensively converted to secondary minerals. Olivine, augite, and plagioclase composite grains identify olivine gabbro as one of the parent rock types. Olivine grains are heavily altered to iddingsite and serpentine, and augite is largely replaced by green fibrous amphibole. Amphiboles are also represented by euhedral (i.e., displaying good crystal faces) hornblende and lenses of colorless tremolite/anthophyllite. The hornblende identifies andesite/diorite as a second parent to this clay. The colorless amphibole (tremolite/anthophyllite) is associated with the alteration/low-grade metamorphism of the olivine gabbro.

In the hand specimen this fabric appears similar to that described by Hayes (1967) for the north Syrian mortaria of Ras el-Basit (which have not been found in the British excavations). Both have a "deep chocolate brown color" (this is common feature of basalt/gabbro derived clays), are "generally free from mica" and are "liberally tempered with white and black grits." The white grits in Storage 2 correspond to plagioclase grains and colorless amphibole (which is soft and superficially resembles lime — otherwise absent in this fabric), and the black grits correspond to all the colored ferromagnesian minerals in this section (in particular augite and hornblende). Hayes also describes "particles of what appears to be crushed glass" and something resembling this description is seen on the surface of the sherd where the angular, dark-green colored ferromagenesian minerals protrude.

This provenance is now confirmed following a review of the local geology. Ras el-Basit is a headland formed by hard basic igneous rocks including the same types of gabbros and associated rocks seen in storage 2. These comprise a late Cretaceous ophiolite.[14] Furthermore, the rocks have been extensively altered to secondary minerals such as serpentine, fibrous amphibole (including anthophyllite), iddingsite, etc., which again closely match the Storage 2 fabric.

Storage 3: Two Sherds from Context 2080, Listed after ***PT461***

Question 25: This is an iron-rich fabric that is characterized by a very high proportion of tectonized material. This is predominantly acid igneous-derived (granite–diorite) and schist, but there is some basaltic material. Limestone is absent, and the lack of dilution by other material may argue for a residual clay developed in a fault/crush zone. There are some complex mineral associations seen here (e.g., quartz–epidote–sphene–hornblende–olivine). This fabric is different from that of **PT450** (above, question 19) which appeared superficially to be similar.

Storage 5

Question 26: The fabric is tempered by calcite spar (vein calcite), which appears as white-gray rhombic grains. This represents very select tempering, the vein material having to be removed from the host limestone, none of which is included in the fabric. Minor soil carbonate. No quartz, basalt, or Euphrates-type minerals. Vein calcite can be sourced from almost any limestone country: No specific provenance is indicated.

NOTES

1. Where, additionally, carbonates are also introduced via groundwater precipitation.
2. Tectonized material has been crushed and deformed as a result of intense faulting and folding (i.e., tectonic activity). Major active fault systems capable of producing tectonized microstructures occur to the north and west of Zeugma.
3. I.e., from the margin of the channel flood-plain.
4. Cooking 1 contains several composite grains of angular basalt (or iron-rich clays produced by basalt weathering) cemented together by soil carbonate (caliche). These are mechanically very weak grains and would not survive alluvial transport beyond short distances.
5. Again it must be stated that there are no direct descriptions of clays from these two regions: Field sampling would be necessary to verify these predictions.
6. It should be noted that provenancing basalts is usually approached by a combination of thin-section analysis and geochemistry. One reason for this is that any given lava flow will show a range of textures, for example depending on whether cooling was rapid (such as for the upper surface of the flow), or slow (e.g., in the center). What this means is that most published references to basalt outcrops emphasize geochemical rather than petrographic characteristics. Further, the bulk chemical analysis of basalts is based on large samples (> 0.5 kg), as this is an analytical requirement to ensure that the sample is fully representative. SEM analysis of the basalt inclusions from pottery cannot give reliable data for comparison, as many of these are small grains, often with a mass of less than 0.1 gm.
7. Arger et al. 2000.
8. Beyarslan and Bingol 2000.
9. Alici et al. 2001.
10. Yurtmen et al. 2000.
11. Mahfoud and Beck 1993.
12. Weinstein et al. 1994.
13. Abdel-Rahman 2002.
14. An ophiolite is a rock unit representing a fragment of former ocean crust that has been thrust-faulted to lie with continental crust. These occur at several locations in the eastern Mediterranean, the largest example being Cyprus. Ophiolites comprise basic igneous rocks (gabbros, basalts, etc.) that have been heavily crushed and altered to new minerals (e.g., serpentine) as a result of thrust-faulting.

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