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Boncuklu Höyük: the earliest ceramics on the Anatolian plateau

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Abstract

In this article 12 fired clay samples and an unfired marl sample from the late 9th and early 8th millennium cal BC site of Boncuklu Höyük (8300–7800 cal BC) in the Konya Plain, Turkey, were analysed by optical microscopy and SEM-EDX. The plant remains in the pottery fabrics were also examined in the variable pressure scanning electron microscope.

Chemical analyses show that the same clays were used for multiple purposes, and more than one type of raw material was used to make the fired clay objects examined. Only one sherd showed signs of having added temper. The presence of scattered organic remains in the fabrics also suggests that the clay was minimally processed. Although the minerals present do not show any optical alteration, the shrinkage of the plant matter and the discolouring of bone inclusions suggested that all but one sample were fired, albeit at a relatively low temperature. These sherds are therefore regarded as among the earliest ceramic vessels known in southwest Asia, although the manufacturing technique was different to that used to make the contemporaneous PPNB ceramics found at Kfar HaHoresh in Israel.

Keywords: Neolithic, earliest ceramics, petrographic analysis, plant inclusions analysis, SEM-EDX

Type of paper: Research article

Highlights:

- Mineralogical and chemical analyses of the earliest ceramics in Anatolia
- SEM-EDX analyses show that the same clays were used for multiple purposes
- Multiple clays used to make ceramics and almost no temper use
- Lack of parallels with ceramics from contemporary Kfar HaHoresh, Israel

Introduction

The aim of this article is to investigate the clay vessels from Boncuklu Höyük, an early Neolithic site in central Anatolia (**Figure 1**). The site, dates to c. 8300 to 7800 cal BC (Baird, 2012a; Baird et al. 2012), much earlier than the accepted date for the introduction of pottery in Anatolia, c. 7000 cal BC. Thus the primary question is whether the clay vessels constitute true ceramics, i.e. were fired intentionally.

Boncuklu Höyük appears to have been established on a rise within a wetland area. Evidence for the use of crop plants at Boncuklu is clearly present but sparse, and foraging was probably more important than farming. Seasonality proxies suggest that the site was occupied throughout the year, but the community may well have included more mobile groups that were absent at different times (Baird et al., 2012, 228-232). Excavation of several areas with a combined exposure of over 400 m^2 has revealed houses with painted floors, bucrania and clay and plaster relief decoration, predating similar practices at the nearby site of Çatalhöyük by about a millennium (Baird et al. 2012, 233-235). A sequence of six buildings, reconstructed one above another, has been excavated in one area (Area K); as at Çatalhöyük, continuous reconstruction in the same place appears to have been important. The buildings at Boncuklu were c. 3×5 m and ellipsoidal with the walls made from mudbrick. The buildings showed evidence of ground-level entry, unlike at Çatalhöyük where entry was from the roof. As at Çatalhöyük, however, there is strong evidence for a highly structured use of internal space, and the presence of plaster installations and painting (Baird et al., 2012). Extensive midden deposits accumulated in open areas and were associated with hearths and lightweight structures that may have formed shelters for work areas.

The inhabitants of Boncuklu made a variety of objects from clay, including vessels, storage structures, figurines, and a large number of other geometric and amorphous objects (Bennison-Chapman, 2014; Fletcher et al., forthcoming). Seventy-seven fragments of fine and coarse clay vessels which can be assigned to the assemblage related to Neolithic phases of occupation at the site were recovered from the site by 2012. Circa one third of these are from securely stratified Neolithic contexts, from different parts of the sequences dated directly by C14. Around half of the stratified examples were isolated sherds within ashy midden deposits and found in areas outside buildings. Middens were associated with activities involving food preparation and consumption, which occurred both outside and inside buildings. Sherds were also found within buildings, mainly in the 'dirty' areas surrounding hearths. One sherd was found in a grave fill in a house, but seems to have been deposited unintentionally when the grave was closed. Given the early date of the site in terms of pottery use in SW Asia the main question discussed here is whether these vessels were fired or only sun-dried, and if they were fired, at what temperature?

The assemblage and sample selection

Five potential categories of ware-types were identified: fine wares, coarse wares, structural wares, fired marl, and unfired marl (table 1; see also Fletcher et al., forthcoming). Two examples of fine wares were from open bowls with flat rim profiles, and diameters of 220 mm and 280 mm. Both rim fragments were decorated with lateral incised lines. Each showed breakage in a manner consistent with poorly smoothed and bonded coils (see Rice, 1987, 127-128, fig. 5.6). Coarse ware sherds were from open bowls, hole mouth pots and jars (**Figure 2**). These were pinched; slab- or coil-built and all had rounded rims (diameters varied from 40 to 220 mm). For some examples, thin layers of clay were used to create the exterior surface. It was not always clear whether the fragments of structural wares were from large vessels, oven walls, or sections of storage bins, perhaps intentionally fired *in situ* to make them more robust. Examples were coil- or slab-built, with well-smoothed outer and inner surfaces. Two sections of rim were found, one from an open bowl (diameter 320 mm) and one from a straight-necked jar (diameter 250 mm). The thickness of the walls suggests they were used for hot stone cooking, a technique that focuses on insulation rather than conduction (Reid, 1989, 171, 175). Other examples of structural wares may be derived from fire installations and thereby have been baked by default. Sherds incorporated into the base of hearths have been found in the midden area (Area M) at Boncuklu; possibly they increased thermal shock resistance and thereby the hearths' use-life (Rice, 1987, 228-230). It is unclear, however, if they were fired before their incorporation into the hearth or as a result of it.

Examples within the fired marl category were thought to be broken/detached sections of the basins and channels that have been found *in situ* on site. They may have helped to drain liquids and a light firing may have increased their durability. Similar 'water-channels' have been identified for the Pottery Neolithic phase at Tell Seker al-Aheimar (Nishiyaki and Le Miere, 2005, 57-59, fig 6). Many of the exterior surfaces were notably rough and pitted. Others showed plant impressions suggesting they may have been formed around or over basketry (Zhushchikhovskaya, 2010, 126-127). Examples categorised as unfired marl were made in the same way with the same materials as the fired marl but not baked at all. No sections of rim were recovered, which is probably indicative of the friable nature of these objects.

Thirteen samples were analysed: a figurine fragment (BK15), two fragments of fine ware vessels (BK1, 2), two fragments of coarse ware vessels (BK4, 5), four examples of structural wares (BK6, 7, 9 and 10); three fragments of fired marl (BK11, 12 and 13) and a section of unfired marl (BK14) (Tables 1 and 2).

Methods

The polished thin sections were analysed using a Leica DMRX polarised light microscope for optical microscopy analysis. A Leica DM4000M microscope was used to examine the distribution of bone fragments in the fabrics.

A Hitachi S-3700N variable pressure (VP) scanning electron microscope with energy dispersive X-ray spectrometry (SEM-EDX) was used to study the samples' microstructure and their chemical composition. Plant inclusions were examined in the same VP SEM using the backscattered electron (BSE) detector at 15 kV or 20 kV accelerating voltage, with a working distance of 10–13 mm, and a chamber pressure of 40 Pa.

The ceramic fabric SEM-EDX analyses were run at an accelerating voltage of 20 kV, with a count rate of 10,000 cps, and a 150 second counting time. The samples were analysed uncoated at a 10 mm working distance, at a chamber pressure of 30 Pa. Four bulk analyses were carried out on each sample at 100x (i.e. covering areas *c.* 1.4×1.0 mm), using Oxford Instruments standards. Ten elements (Na, Mg, Al, Si, P, K, Ca, Ti, Mn, and Fe) were quantified and the results were converted into oxide percentages. These percentages were normalised (oxygen by stoichiometry) to take into account the fact that oxygen and carbon are not measured (Table 3). No other oxides were detected; detection limits for each element vary but are typically 0.1–0.4%.

Principal component analysis (PCA) was used to interpret the SEM-EDX results and to help in the identification of chemical groups based on the concentration of the oxides. The PCA of the correlation matrix was performed using PAST v.2.17 (Hammer et al. 2001). All principal components were examined.

Results

Petrographic analysis

Four petro-fabric groups (fabrics) were identified (see detailed description in Table 2; **Figures 3, 4**). Fabric 1, which includes one fine ware fragment (BK1), one structural ware fragment (BK7) and two fired marl samples (BK11, 12), is made of a very fine and slightly micaceous marl, with fine and scattered quartz grains, muscovite, occasional and very fine shell fragments, pyroxene, fine bone fragments (up to 0.4 mm long), very occasional and fine clay pellets, ilmenite, and iron oxides (**Figure3 top left and right)**; occasional scattered charred plant matter is present in the structural fragment. Its subgroup, with fewer inclusions, comprises the figurine (BK15) and a fragment of fired marl (BK13); these two samples are almost identical (**Figure 3bottom left**).

Fabric 2 included a coarse ware (BK5) and structural ware (BK6). This fabric is very homogeneous and calcareous, with some fine and well-sorted quartz, calcareous pellets (microcrystalline calcite), feldspar, fine muscovite, calcareous sandstone, occasional metamorphic and igneous inclusions (probably rhyolite), clay pellets, amphibole and scattered bone fragments. There are very occasional voids left by the burning of plant matter, which was probably naturally present in the clay (**Figure 3bottom right**). Fabric 2 *subgroup a* (another structural ware, BK9) is very fine with some biotite, occasional bone fragments, sphene, and very few elongated voids probably left by the burning of plant matter. Fabric 2 represents a different clay source to Fabric 1. It is slightly micaceous with fine mainly sub-rounded igneous inclusions absent in Fabric 1, and more abundant bone fragments.

Fabric 3, comprised a fine ware fragment (BK2) and contained very fine quartz sand, shell fragments, very abundant calcareous fragments, plagioclase, igneous inclusions, occasional sub-rounded calcareous sandstone fragments, common bone fragments (**Figure 4 top left and right**), and occasional charred plant matter. Its *subgroup a* (structural ware BK10) contains some dolomitic fragments (**Figure 4 bottom left**), fewer bone fragments, and was probably tempered with plant matter (charred organic remains with clear orientation). Fabric 3 *subgroup b* (coarse ware BK4) contained coarser quartz sand, and occasional fine bone fragments (**Figure 4 bottom right**). Fabrics 2 and 3 might represent different areas of the same clay outcrop. Fabric 3 contains more abundant bone fragments (see also EDX for high phosphorus content); and sample BK4 (Fabric 3 *subgroup b*) has coarser and more abundant calcareous fragments than Fabric 2. The unfired marl fragment (BK14) designated Fabric 4 is derived from a further clay source, which is rich in opaques, phytoliths, with some iron oxides, biotite, and occasional bone fragments (**Figure 5left and right**).

In summary, different sources were exploited to manufacture the early ceramics at the site: Fabric 1 is made of a fine-grained marl, whereas Fabric 1 *subgroup a* contains some fine metamorphic fragments. The unfired marl analysed as a reference material (Fabric 4) is very different to that used for the Fabric 1 pottery. The clays in Fabrics 2 and 3 were collected from calcareous outcrops and contain very fine igneous inclusions, including amphibole and sphene; Fabric 3 also contains some fine sandstone fragments. All samples in Fabrics 1-3 were low-fired.

SEM-EDX analyses of the samples' microstructure and chemical composition

All samples in polished section were analysed by SEM-EDX. SEM imaging suggested low-firing temperatures, as the clay microstructures show no signs of initial sintering or filaments which are starting to vitrify (e.g. see **Figures 6 left and right** and **7**).

The EDX results correspond well to the petro-fabric groups identified (Table 3; **Figure 8**). Principal components 1 (56%) and 2 (26%) account for most of the variance in the EDX data; components 3 and 4 each represent less than 7% of variance.

Fabric 1 and its subgroup (six samples – BK1, 7, 11, 12, 13, 15) are chemically very similar (Table 3). As they are from a marl outcrop, they contain very high levels of calcium oxide (36.58–41.28%). They also have high magnesia contents (average 3.9%), relatively low silica and alumina (averages respectively 37% and 11%), and some iron oxide (4.3%). The high calcium oxide and magnesia contents reflect the clay type (marl), not inclusions.

The two Fabric 2 samples (BK5 and 6) are chemically very similar to each other, with less magnesia and calcium oxide than Fabric 1, similar iron content, and higher alumina and silica. Fabric 2 *subgroup a* (BK9) has slightly higher potash and soda, and lower calcium oxide contents. Fabric 3 (sample BK2) would chemically fit within Fabric 2 values, but has lower alumina and higher phosphorus content, due to the many bone fragments. Fabric 3 *subgroup a* (BK10) contains higher calcium and lower iron oxide and silica than Fabric 3. Fabric 3 *subgroup b* (BK4) has a slightly higher silica content than Fabric 3 (due to the coarser and more abundant quartz sand) and lower iron oxide. Fabric 4 (the unfired marl, sample BK14) has relatively low calcium oxide (24.7%), iron oxide (3.2%) and alumina

(9.0%), moderate magnesia, a relatively high silica content (54.6%), and high phosphorus (1.9%) (also related to the presence of scattered bone fragments).

Analysis of the plant inclusions using VP SEM

Examination of structural ware sample BK7 (fabric 1) revealed evidence of numerous plant fragments of different sizes and shapes, either as voids left in the fabric where they have been burned out, or as surviving remnants of monocotyledonous stems and epidermal leaf cells. The voids and plant fragments appear to be in random orientation, such as might be seen in naturally-occurring organic-rich clays, rather than in an aligned orientation, which can be typical of deliberately-added plant temper. In one example (**Figure 9**) there is a pronounced halo-shaped void around the tiny monocotyledonous stem fragment (visible in transverse section), which is typically formed as the result of firing of ceramics or, as is relevant in this instance, from the ceramic being in contact with the heat of a hearth or fire-installation. When exposed to an even, consistent heat, the plant stem would contract and shrink away from the surrounding clay leaving a distinctive halo-shaped void. In this example (**Figure 9**), much of the monocotyledonous stem has survived, suggesting that relatively low temperatures were involved, probably less than 500°C. This is further substantiated by the survival of very fine, thread-like epidermal plant cells.

Coarse ware samples BK4 and BK5 (Fabric 3 *subgroup b* and Fabric 2) showed evidence of some plant inclusions, mostly present in the form of surviving remnants of monocotyledonous epidermal leaf cells, but occasionally by voids. Judging from their random orientation, these plant remains are more likely to be indicative of organic-rich clays rather than a deliberately-added temper. As observed for BK7, there are examples of halo-shaped voids around tiny monocotyledonous stem fragments (visible in transverse section), where the firing or heat-exposure has induced shrinkage of the plant fragments away from the surrounding clay matrix (**Figure 10**).

Structural ware sample BK10 (Fabric 3a) revealed many surviving plant inclusions, mostly lengths of monocotyledonous stems and leaves. In some instances the plant inclusions appear to be in a linear orientation, which may signify that they represent added temper. In addition there are smaller fragments of randomly-distributed monocotyledonous epidermal leaf cells and tendril-like portions of hairy monocotyledonous stalks. As observed for BK7 (as well as for BK4 and BK5), the fact that so many of the monocotyledonous stem and epidermal leaf cell fragments have survived (and were not completely burned-out or ashed) is suggestive of relatively low temperatures.

Discussion

Pottery Technology at Boncuklu Höyük

Although the minerals present in the thin sections do not show any optical alteration, three observations suggest that the fine and coarse ware fragments were fired intentionally:

- the presence, shape and position of voids left by the charring or burning-off of plant matter in some of the sherds/artefacts,
- the colour of bone fragments in all fabrics, which has changed from yellowish to orange,
- the strong similarities between the optically-active vessel fabrics and those of the fired marls (extinction identifiable rotating the section in cross-polar light; see Quinn, 2013, 84).

Nevertheless, all the sherds, structural fragments and a possible fragment of fire installation were fired at low temperatures, not exceeding 500°C, as the sherd fabrics are birefringent (optically active), sintering (when particles begin to fuse together) was not identified; see also SEM **Figures 6**and **7**), and the bone fragments have a low refractive index (Squires et al., 2011). In some samples, plant matter was completely burnt out of the clay, but in a couple of samples it is still partly visible and well-preserved (e.g. BK10). Phytoliths are present in some of the fabrics, but they survive high firing temperatures, up to 1000°C (Piperno, 2006, 89). Additionally, the samples analysed are rather rich in carbonates. Experimental work on calcareous clays shows that $CaCO_3$ seems to lower the temperature at which extensive vitrification is reached (Tite and Maniatis, 1975, 22). This implies that the potsherds were fired at a temperature lower than 850°C. In addition, the preservation of micas and the presence of microcrystalline calcite suggest a firing temperature lower than 750°C in oxidizing conditions (Maniatis and Tite, 1981). The occasional shell fragments are structurally intact, indicating a low firing temperature (<650 °C); it has been demonstrated experimentally that the conversion of aragonite to calcite takes place at 400-450 °C, without visible alteration of shell structures (Maritan et al., 2007). The apparently burnt bone fragments could have already been burnt when incorporated into the clay.

Low firing is typical of most early Neolithic pottery production in Europe: fabrics are usually optically active and contain specific minerals which indicate firing at ca. 600-700°C in bonfires (e.g. abundant micas, amphiboles and calcite; see Muntoni et al., 2009, 325). Early Neolithic (6th millennium cal BC) pottery from the Adriatic region and the central Balkans was low-fired, at temperatures not exceeding 600-750°C (e.g. Spataro 2002, 2011). The technology of the early pottery at Boncuklu, approximately 1000 years earlier than the widespread diffusion of ceramics in this region, might have been influenced by other already well-developed technologies, such as the preparation of lime for plaster using kilns or enclosed fires in the PPN (e.g. Gourdin and Kingery 1975; Goren and Goring-Morris, 2008), with temperatures exceeding 800°C, although intriguingly there is no evidence for fired lime production or use at Boncuklu.

The samples analysed for the most part were not tempered. Except for Fabrics 2 and 1 *subgroup a*, all fabrics contain scattered, fine bone fragments measuring between 0.09 mm and 1.2 mm (Table 2). The bone fragments were just lightly heated, as they are not highly refractive (Y. Goren, pers. comm. 2014) and the canaliculi are preserved (see Squires et al., 2011, table 2; Bennett, 1999). The bone was probably not intentionally added but was already present in the raw materials used; perhaps the clay was collected or prepared in the same area as bones were smashed to extract marrow, although the fragments are too small to exclude any species identification. Only one example (BK2, Fabric 3) showed a high enough density of bone inclusions to suggest that it might have been deliberately tempered with bone fragments, as fine bone fragments were more abundant than in the other samples (**Figure 4 top left and right**). Bone temper is rare in early pottery production, and is unknown in the earliest pottery from southern Europe and in the Levant.

The diverse scatters of plant fragments in the pottery fabrics are consistent with those found in naturally organic-rich clays. It follows, therefore, that the clay was only minimally processed. One structural ware fragment (sample BK10) however, was probably plant-tempered (see **Figure 4 bottom right**). Organic temper is among the most common temper-types in mudbricks and the earliest pottery production (e.g. Biton et al., 2014; Spataro, 2011). Plant fragments in pottery, mudbricks and ovens, whether deliberately added as temper or present as naturally-occurring components of organic-rich clays, have the advantage of opening up the fabrics, potentially reducing shrinkage, cracking and thermal shock (Rice, 1987, 406-413).

As the vessels were made with clays from various sources, it seems unlikely that their firing at low temperatures was accidental, as this explanation would require multiple accidents. The question of whether these products are ceramics or not needs to be addressed by clarifying the meaning of the term ‘ceramic’. According to Hamer (1975, 51), ceramic means a “clay product made permanent by heat”. In Valde and Druc (1999, 5) ceramic is also a "general term for all objects made from a dominantly silicate material which have been transformed in physical state by heat (firing)". Archaeometric analyses cannot determine whether sherds were fired accidentally or intentionally, but, according to these definitions, intentionality is not essential. As there is no agreed lower limit to the firing temperature required for fired clay to be classified as ceramic, and they have been irreversibly transformed by heat, the Boncuklu Höyük samples can be considered ceramics.

Although only four potsherds and a figurine fragment were analysed, three different clay sources were represented among the portable artefacts. The macroscopically identified fine wares (samples BK1 and BK2) were manufactured with different clays. One fine-ware potsherd and the figurine (samples BK1 and 15; Fabric 1 and its *subgroup a*) were made of an extremely fine locally available marl, without the addition of any inclusions. Fabric 1 and its *subgroup a* also include an oven structure (BK7) and three fired marls. These six products are chemically very consistent (see **Table 3** and **Figure 8**). The other potsherds analysed (samples BK2, 4 and 5; Fabrics 2 and 3) were made with different siltier and much coarser clays, with abundant inclusions, including volcanic minerals, and microcrystalline calcite. These fabrics were also used to make a fire installation and other possible structural components at the site. Thus there is no indication that any of the portable ceramic objects were imported to the site.

Regional parallels

Excavations at the site of Pınarbașı, 30 km southeast of Boncuklu (Figure 1), have explored deposits dating c. 9000-7800 cal BC and thus overlapping with the occupation at Boncuklu (Baird, 2012a; Fairbairn et al., 2014). Pınarbașı shows much less evidence of the household practices seen at Boncuklu, however, and no evidence for plant cultivars or early pottery vessels was recovered from the site. The earliest vessels at Çatalhöyük date to the earlier part of the 7th millennium cal BC and are therefore later than those from Boncuklu (Bayliss et al., 2015, 16). Parallels at other sites in the region (Suberde, Erbaba, Alan Höyük, Yumuktepe, Tarsus, Pınarbaşı-Bor, Kösk Pinar, Musular, Beldibi, Belbaşı, Kuruçay, Hacılar, Höyücek, Bademağaci) are also linked to later ceramic Neolithic phases after c. 7000 cal BC (Last, 2005, 127, 137-138; Schoop, 2002). Thus it would seem that at present, the pottery recovered at Boncuklu is the earliest known for central Anatolia and is contemporaneous with the other early instance in southwest Asia, at Kfar HaHoresh in Israel (Biton et al., 2014). Given the current evidence, the pottery made at Boncuklu contributes to the debate concerning how sustained pottery production emerges in such a short timeframe around

7000 BC. It seems sensible to suggest there may have been an extended period prior to this date within which different types of pottery were made, possibly intermittently.

In contrast to the Boncuklu Höyük ceramics, the twelve sherds from Middle PPNB Kfar HaHoresh analysed by optical microscopy show variations in temper: some were made of marl tempered with dung, one was made of marl and not tempered, and one made of *terra rossa* was mineral-tempered (Biton et al., 2014, Table 2). They were all fired at a maximum of 500°C. The later Pre-Proto Hassuna pottery (Late PPNB) of the Khabur basin in north-east Syria was mainly mineral-tempered (Nishiaki and Le Mière, 2005, 61; firing conditions are not discussed). Mineral temper was also used for the earliest pottery production (7000-6800 cal BC) at Tell Sabi Abyad, in the same region (Nieuwenhuyse et al. 2010). Therefore the fine fabrics identified at Boncuklu have not been found at PPNB sites with fired clay vessels examined to date (e.g. Biton et al., 2014; Nishiaki and Le Mière, 2005). Fine marls were used however, to make fired clay figurines at PPNA Gilgal I (Goren and Biton, 2010). As at Gilgal I, figurine production at Boncuklu Höyük demonstrates a sophisticated sourcing of fine calcareous clay as their raw material, which when fired, produced artefacts that were relatively durable.

Conclusions

This study has shown that at least three different pastes were used to produce the samples analysed. The figurine examined was made using very fine marl, almost inclusion free, and very similar to that used for the production of a one of the fine ware sherds examined and also the 'fired marl' channel-like structures. The presence of scattered organics in the fabrics implies that for most examples of pottery, the source clay was barely processed. Suitable clays for potting appear to have been readily available around the site. The presence of fine bone fragments, in most examples suggests that clays may have been worked in or near an area where animal carcasses were processed. The potsherds examined do not appear to have been tempered, except for one which might have been bone-tempered; this would be one of the earliest examples of the use of bone as a ceramic temper. Another sample, probably derived from a structure such as a fire installation, may have included organic temper[1]. All the pots were fired at low temperatures, probably not exceeding 600°C and in some instances probably below 500°C.

[1] Vegetal matter and dung were commonly used for the sun-dried bricks of the PPNA (e.g. see Bar-Yosef and Gopher, 1997).

The relatively small number of fragmentary fired clay vessels at Boncuklu Höyük appears to be the earliest pottery found on the Anatolian plateau. This situates the appearance of pottery production within a context where foraging was dominant and sedentary behaviour was in its early stages. It is interesting to note therefore that small scale pottery production emerges in a context of low level food production, analogous to the early adoption of pottery by hunter-gather groups elsewhere around the globe, such as in East Asia (e.g. Jordan and Zvelebil, 2010).

One further point emerges from the detailed analysis of source materials and technology of what can be regarded as, regionally, an early, small scale and experimental phase of pottery production. When compared to Kfar Hahoresh, a contemporaneous example of experimental and small scale production in SW Asia, evidence suggests significant diversity in production technology and preferred types of source material. So generalised ideas about pottery may have been communicated across the region in very early phases of pottery production in SW Asia, but apparently little very specific technological know-how was transferred as part of this process.

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Captions:

Table 1. Boncuklu Höyük: fired clay objects recovered during 2012 excavation season.

Table 2. Boncuklu Höyük: petrographic description of the clay samples analysed.

Table 3. Boncuklu Höyük: SEM-EDX compositional results of four bulk analyses per sherd at 100x, with mean (blue rows) and standard deviation (white rows). Results are reported as normalised % oxides. The detection limits for each element are variable but are typically 0.1 - 0.4%. The relative precision (reproducibility) is about 1% for the major elements, 10% relative for concentrations in the range 5-20% and it deteriorates as the detection limits are approached.

Figure 1. Location map of the sites mentioned in the text: 1. Boncuklu Höyük, 2. Çatalhöyük, 3. Pınarbașı.

Figure 2. Sample of vessel rim fragments recovered showing morphological variation: open bowls, hole mouth vessel, jar neck. © The Boncuklu project, drawing by Caroline Hebron.

Figure 3. Photomicrographs of thin sections of samples BK1 (fine ware; Fabric 1; top left), BK11 (Fabric 1; top right), BK15 (a figurine; Fabric 1 *subgroup a*; bottom left), and BK5 (coarse ware; Fabric 2). All microphotographs were taken in cross polarised light (XPL); scale is in microns. Image: M. Spataro © The Trustees of the British Museum.

Figure 4. Photomicrographs of thin sections of samples BK2 (fine ware; Fabric 3; top left), BK2 seen using the fluorescent light of the Leica DM4000M (Fabric 3; top right), BK10 (a structural sample; Fabric 3 *subgroup a*; bottom left), and BK4 (coarse ware; Fabric 3 *subgroup b*). All microphotographs were taken in XPL; scale is in microns. Image: M. Spataro © The Trustees of the British Museum.

Figure 5. Left: photomicrograph of thin section of sample BK14 (unfired marl; Fabric 4), taken in XPL. Right: SEM backscattered electron image of sample BK14, showing phytoliths. Scales are in microns. Images: M. Spataro © The Trustees of the British Museum.

Figure 6. SEM backscattered electron image of sample BK2 (fine ware; Fabric 3; left) showing presence of bone fragments and (right) the non-vitrified matrix at high magnification. Image: M. Spataro © The Trustees of the British Museum.

Figure 7. SEM backscattered electron image of sample BK15 (a figurine; Fabric 1 *subgroup a*), showing a low-fired matrix with clearly visible clay filaments. Image: M. Spataro © The Trustees of the British Museum.

Figure 8. Principal components analysis of SEM-EDX compositional data, principal components (factors) 1 and 2. PCA was carried out on the correlation matrix of the averaged results of 4 bulk analyses of each sample, using Past v.2.17 (Hammer et al. 2001; http://folk.uio.no/ohammer/past/index_old.html). Samples are labelled according to petrographic fabric grouping. Vectors (green lines) show the loadings for each oxide, which correspond to the relative abundances of each oxide in different samples. Results have been standardised.

Figure 9. VP SEM image of BK7 hearth or fire installation showing a halo-shaped void around the tiny monocotyledonous stem fragment (visible in transverse section), formed as a consequence of the plant stem shrinking away from the matrix when the ceramic was fired or heated. Image: C.R. Cartwright © The Trustees of the British Museum.

Figure 10 VP SEM image of BK5 coarse ware showing a halo-shaped void around tiny monocotyledonous stem fragments (visible in transverse section), where the firing of the ceramic has induced shrinkage of the plant fragments away from the surrounding clay matrix. Image: C.R. Cartwright © The Trustees of the British Museum.

Table 1.

Ware category	Count	Weight	Description	Thickness of vessel walls (mean value mm)	Macroscopic fabric	Morphology
Neolithic fine: Samples BK1, 2, 15	7 (9%)	101.4 (6.3%)	Fine, well-sorted calcareous marl. Fabric and surface similar to figurines from the site.	12.7	Firm with a smooth or sub-angular break and colour varied from white (10YR 8/2) to light grey (10YR 7/2) with no dark cores.	Open bowls with flat rim profiles. Some rims decorated with lateral incised lines. Vessels both coil and slab-built.
Neolithic coarse: Samples BK4,5	21 (27.3%)	420 (26%)	Medium- or low-fired clay marl with vegetal and grit inclusions.	14.8	Firm to soft with angular, sub-angular and smooth breaks observed. Fabric colour varied from very pale brown, grey, dark grey and pink (10YR 7/3, 5/1, 7.5YR 7/4, 8/4, 4/0, 2.5YR 5/0) with 3 examples having reduced fabrics or dark cores.	Open bowls, holemouth pots and jars that were pinched, slab- or coil-built. Some examples had thin layers of clay slabbed over the vessel body to create the exterior surface.
Neolithic structural: Samples BK6,7, 9, 10	15 (19.5%)	917 (56.9%)	Medium- or low-fired clay marl with prominent vegetal vegetal and grit inclusions.	20	Firm to soft with angular and sub-angular breaks observed. Fabric colour varied white, pinkish white, very pale brown, light grey, light brownish grey and pink, (10YR 8/2, 8/3, 7/3, 7/1, 6/2, 7.5YR 8/2, 8/4, 7/4, 5YR 7/4) with 8 examples having reduced fabrics or dark cores.	Thick sections of vessel/bin/heart/possible fire installation. Coil- and slab-built sections with well-smoothed outer and inner surfaces.
Fired marl: Samples BK11, 12, 13	9 (11.7%)	59.6 (3.7%)	Compressed marl. Very lightly baked.	9.7	Firm to soft with a sub-angular or smooth break. Fabric colour varied from white, light grey, very pale brown and grey (10YR 8/1, 8/2, 7/2, 7/3, 7.5YR 6/0, 5/0) with 5 examples having reduced fabrics or dark cores.	Basins/channels with very rough exterior surfaces, some marked with plant impressions, when compared to the smoothed interior; suggesting they were made by pressing clay marl directly into baskets or moulds in the earth
Unfired marl: BK14	25 (32.5%)	113.8 (7.1%)	Compressed marl but unfired and therefore highly friable.	7.7	Soft and friable once broken with a smooth or sub-angular break. Fabric colour varied white, very pale brown, light grey, grey, dark grey (10YR 8/1, 8/3, 7/1, 7/3, 6/1, 4/1, 5Y 8/1).	As above.

Table 2

Fabric	Matrix	Petrographic description
Group 1 (four samples: BK1 [fine ware], 7 [structural], 11 [fired marl], 12)	Brownish-red very fine marl with high magnesia content, slightly micaceous	Occasional: extremely fine and scattered quartz grains (<5%), some muscovite (>2%), plant matter (BK11), pyroxene, scattered fine bone fragments (burnt bones), ilmenite, iron oxides, very fine shell fragments, fine clay pellets. BK7 contains some organics and bone fragments; BK1 probably contains a bone fragment and very fine scattered serpentine (BK1).
1 *subgroup a* (two samples: BK13 [fired marl], 15 [zoomorphic figurine; fine ware])	Brown marl	Occasional: fine quartz (0.02×0.02 mm), fine clay fragments, occasional fine muscovite mica, very rare and fine shell fragments, iron oxides. Very occasional: plagioclase, very fine metamorphic rock fragments; bone fragments in BK13.
Group 2 (two samples: BK5 [coarse ware], 6 [structural])	Brownish-red calcareous	Common: well-sorted fine quartz (<10%; typical size 0.03×0.03 mm), calcareous pellets, feldspar (<2%), some bone fragments, fine muscovite. Occasional: pyroxene, calcareous sandstone, fine metamorphic and igneous inclusions, amphibole (BK5), occasional organic matter (not tempered; some of the charred organic remains are still present in the fabric in BK5), clay pellets.
2 *subgroup a* (sample BK9 [structural])	Brownish-red calcareous	Common: well-sorted sub-angular quartz (7%; 0.04×0.03 mm), feldspar, bone fragments. Probably there was very rare elongated chaff probably naturally present (as only two voids identified), but very occasional elongated voids left by organic matter which burnt out of the clay. Occasional: calcite, red clay fragments, sphene, fine igneous inclusions (feldspars aggregates), pyroxene, biotite, shell fragments, clay pellets, amphibole.
Group 3 (sample BK2 [fine ware])	Brownish-red, mainly calcareous but in some areas non- calcareous	Abundant: calcareous pellets. Common: fine and well-sorted quartz (>10%; typical size 0.03×0.02 mm), recurrent bone fragments with fibro-lamellar complex type with reticular canals (Cuijpers Saddha). Some of the bones are isotropic (Y. Goren, pers. comm. 2015). Occasional: vegetal matter (which is partly still in the fabric), biotite, hornblende, calcareous sandstone, shell fragments, phytoliths, opaques, plagioclase, a soil pellet, sub-rounded to rounded igneous inclusions.

Table 2

3 *subgroup a* (sample BK10 [Neolithic structural])	Brown and calcareous	Abundant: calcareous pellets. Common: quartz (>10%; typical size 0.03×0.02 mm), plant matter (probably deliberately added; some of which is still in the fabric), biotite, feldspar. Occasional: bone fragments, dolomitic grains, phytoliths, very fine rounded igneous inclusions, fine calcareous sandstone fragments (?), amphibole.
3 *subgroup b* (sample BK4 [coarse ware])	Brown calcareous	Abundant: calcareous fragments. Common: well-sorted quartz (15%; typical size 0.04×0.03 mm), some plagioclase (>2%), Occasional: bone fragments (up to 3mm long), oblique longitudinal cross section of shells, biotite, amphibole, phytoliths, soil pellets, scattered naturally present organic matter, igneous inclusions
Group 4 (sample BK14 [unfired marl])	Brown marl	Abundant: opaques, phytoliths. Common: iron oxides and biotite. Occasional: bone fragments.

Table 3

Petro-fabric group	Object	Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO
Group 1	Fine sherd	BK1	0.49	3.73	10.85	36.67	0.18	2.04	41.24	0.59	0.10	4.11
		s.d.	0.04	0.05	0.05	0.54	0.01	0.06	0.48	0.03	0.07	0.12
Group 1	Structural/possible fire installation	BK7	0.50	4.24	11.04	35.40	0.19	3.14	40.12	0.50	0.09	4.80
		s.d.	0.06	0.17	0.11	0.49	0.16	0.18	0.76	0.02	0.11	0.93
Group 1	Fired marl	BK11	0.57	3.99	11.53	39.23	0.44	2.77	36.58	0.48	0.03	4.40
		s.d.	0.04	0.30	0.18	0.87	0.17	0.17	1.15	0.06	0.06	0.13
Group 1	Fired marl	BK12	0.52	4.04	10.93	38.39	0.05	2.30	39.48	0.56	0.00	3.75
		s.d.	0.04	0.05	0.29	0.71	0.10	0.07	0.91	0.03	0.00	0.18
Group 1 *subgroup a*	Fired marl	BK13	0.43	3.54	10.96	36.38	0.28	2.52	40.77	0.50	0.09	4.56
		s.d.	0.03	0.11	0.31	0.57	0.05	0.06	0.64	0.05	0.11	0.24
Group 1 *subgroup a*	Zoomorphic figurine	BK15	0.47	3.70	11.10	35.72	0.21	2.67	41.28	0.53	0.16	4.17
		s.d.	0.03	0.03	0.15	0.37	0.27	0.05	0.40	0.04	0.03	0.08
Group 2	Coarse sherd	BK5	0.97	2.50	13.68	54.07	0.65	2.85	20.22	0.71	0.00	4.35
		s.d.	0.21	0.14	0.44	2.14	0.14	0.06	1.93	0.06	0.00	0.12
Group 2	Oven/structural	BK6	0.90	2.45	13.75	53.55	0.78	2.74	20.92	0.72	0.03	4.18
		s.d.	0.11	0.08	0.57	0.77	0.28	0.09	1.25	0.01	0.06	0.15
Group 2 *subgroup a*	Oven/structural	BK9	1.36	2.45	13.63	56.46	0.42	3.54	16.71	0.85	0.00	4.59
		s.d.	0.14	0.18	0.67	0.66	0.19	0.09	0.82	0.22	0.00	0.41
Group 3	Fine sherd	BK2	1.09	2.13	12.42	56.78	1.27	2.39	18.80	0.77	0.03	4.34
		s.d.	0.08	0.07	0.25	2.60	0.86	0.08	2.39	0.12	0.07	0.25
Group 3 *subgroup a*	Oven/structural	BK10	1.02	2.86	12.50	52.27	0.26	2.56	24.02	0.72	0.00	3.82
		s.d.	0.11	0.10	0.92	1.25	0.25	0.11	1.27	0.17	0.00	0.23
Group 3 *subgroup b*	Coarse sherd	BK4	1.28	2.62	12.47	58.11	0.16	2.75	18.08	0.68	0.03	3.82
		s.d.	0.10	0.49	0.25	0.94	0.20	0.05	1.48	0.19	0.06	0.24
Group 4	Unfired marl	BK14	0.51	3.68	9.05	54.55	1.91	2.10	24.67	0.37	0.00	3.19
		s.d.	0.04	0.06	0.25	2.61	0.09	0.14	3.17	0.04	0.00	0.15

Fig 1


Istanbul
Bursa
Ankara
Izmir
Konya
1
2
3
Antalya
Mersin
Adana

Fig 2

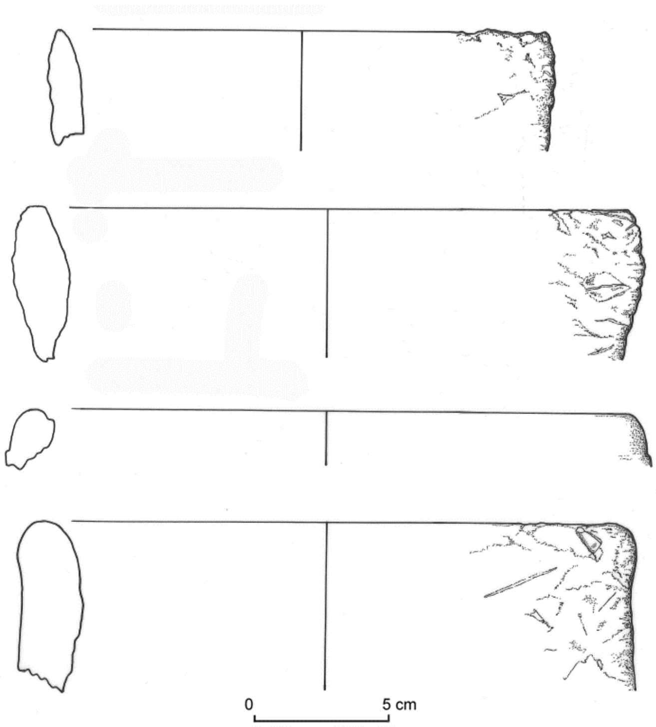
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Fig 3

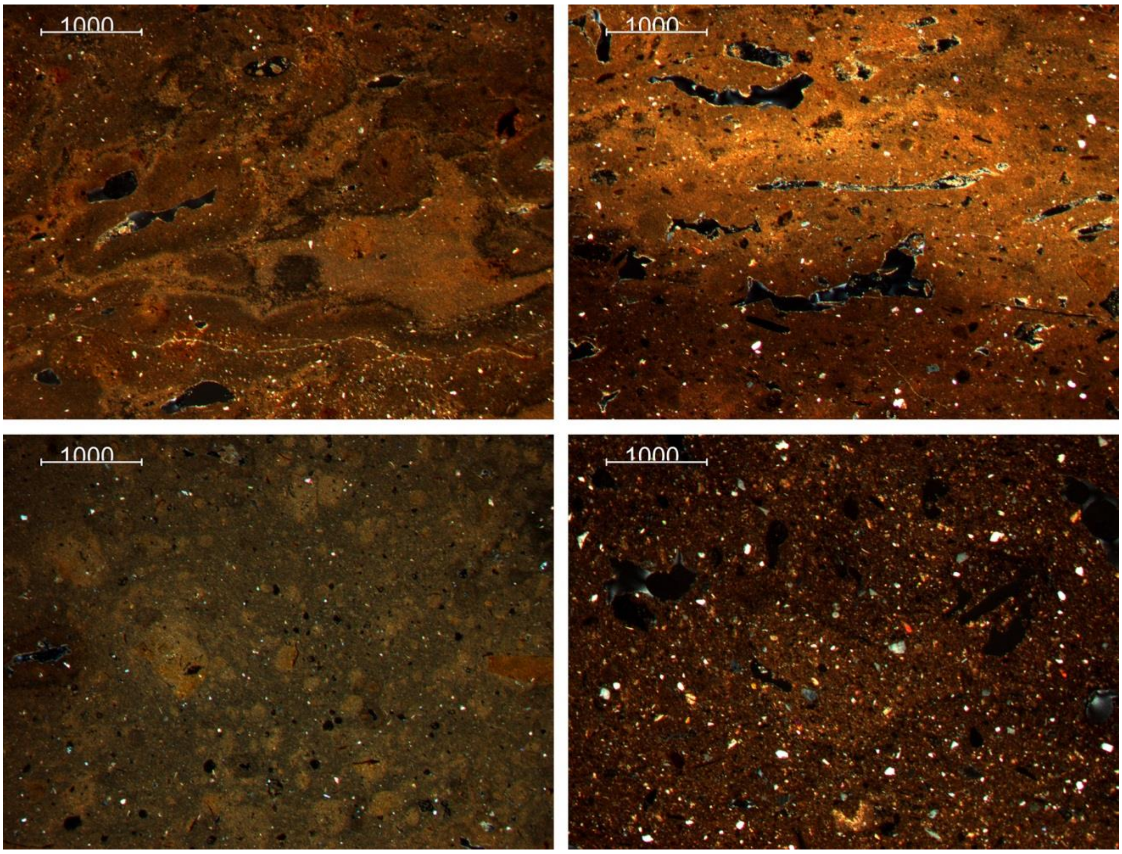
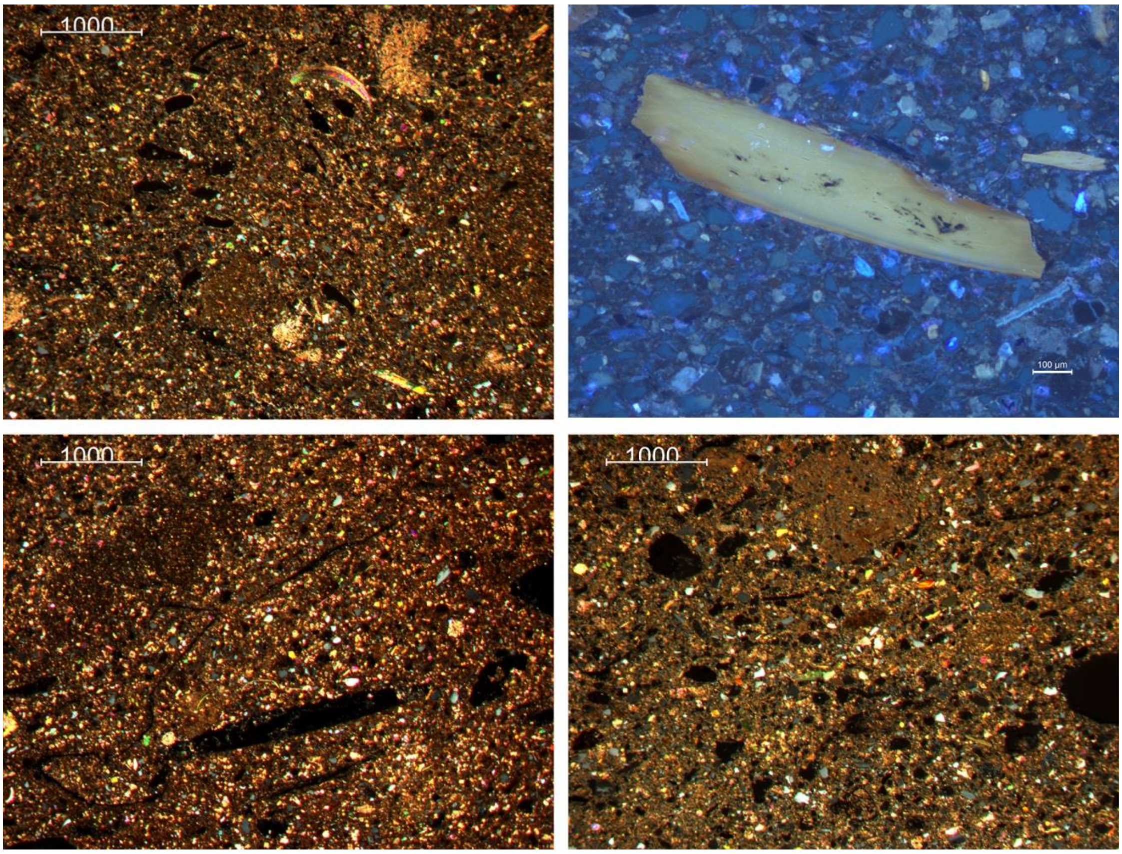


Fig 4



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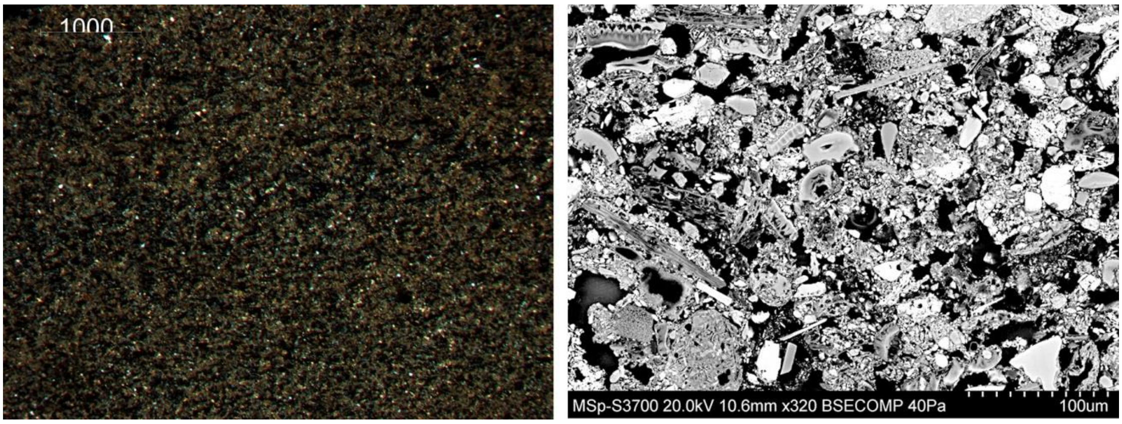

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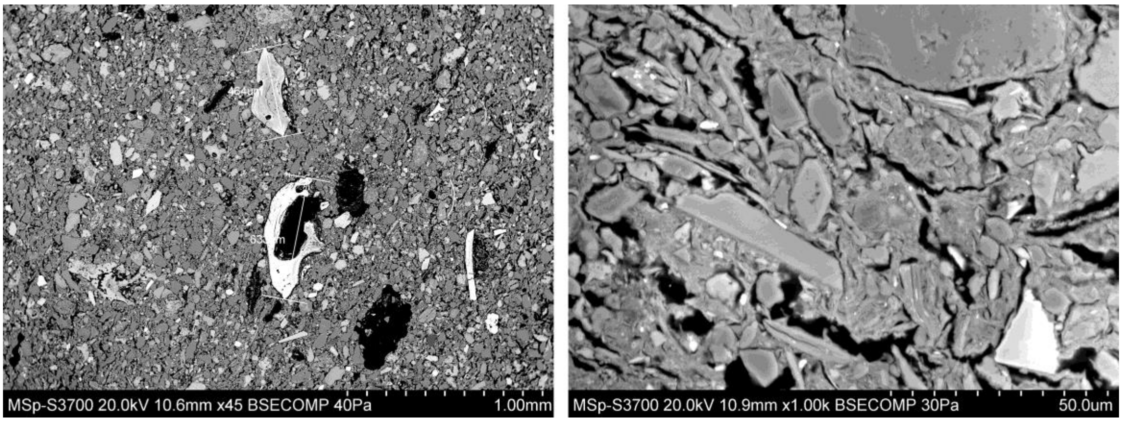

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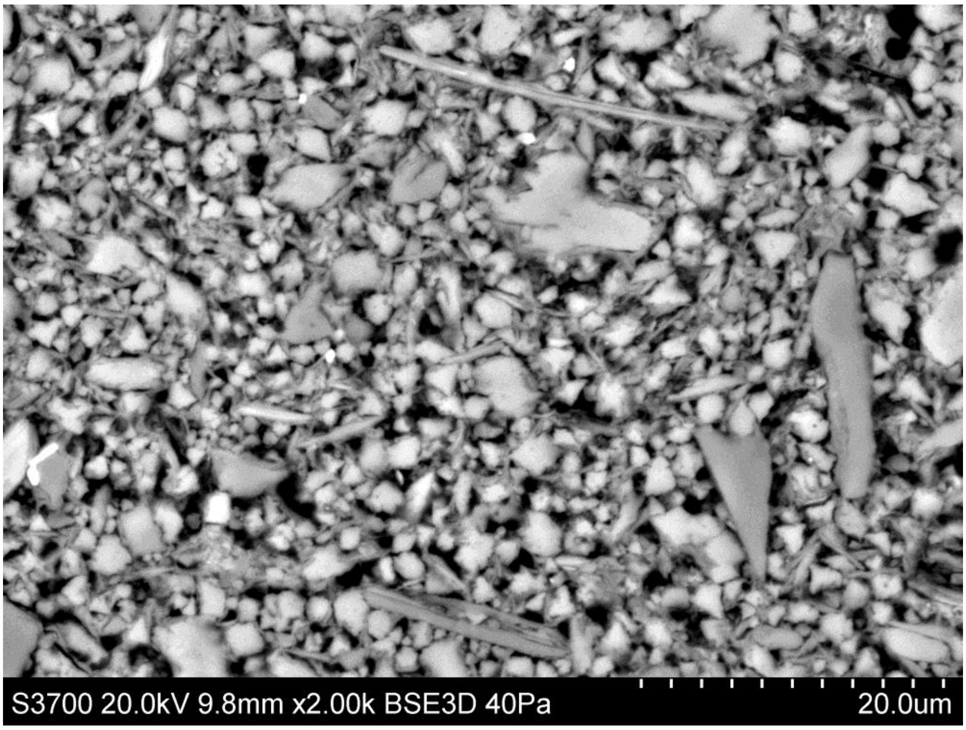
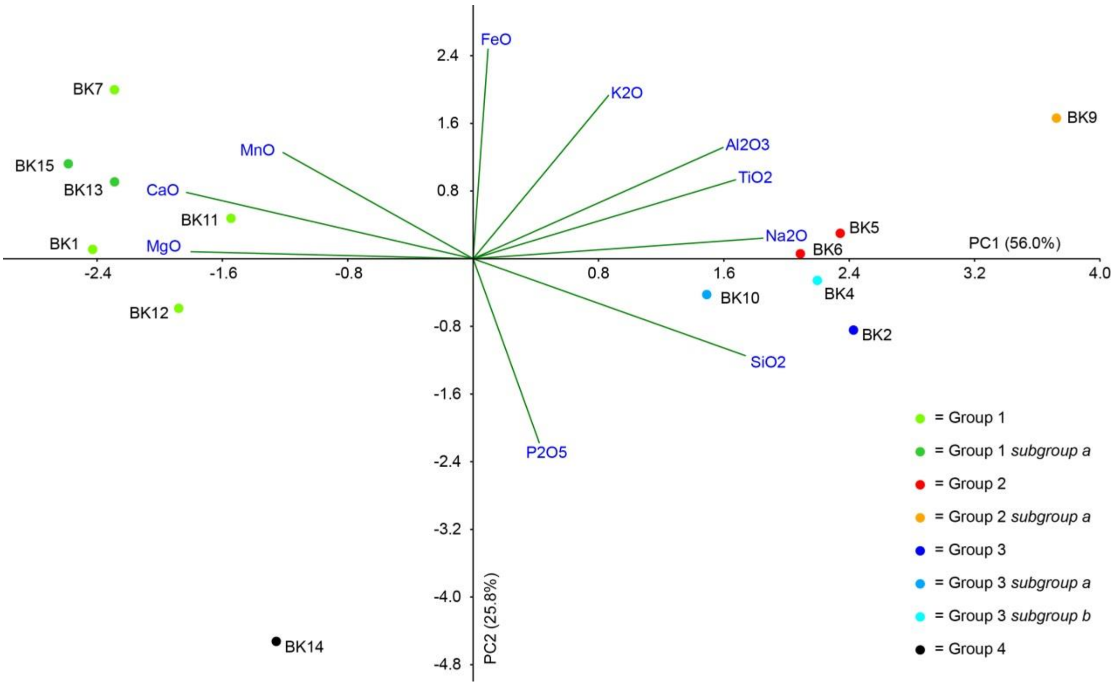


Fig 8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TiO2
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CaO
MgO
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SiO2
P2O5
BK7
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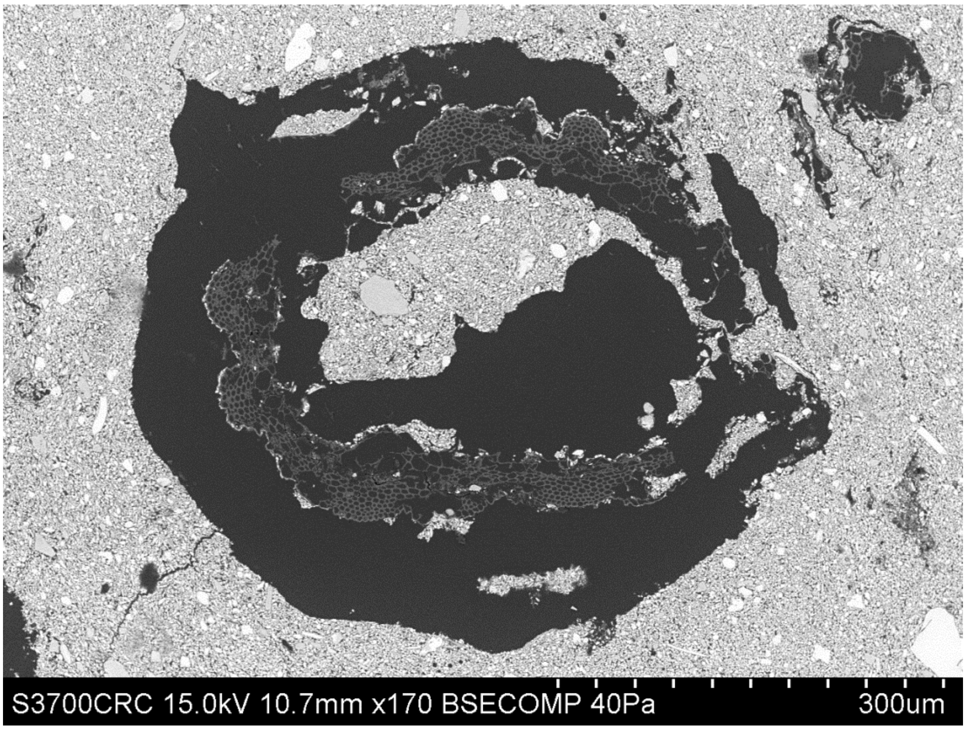
BK12
BK14
BK9
BK5
BK6
BK4
BK10
BK2
2.4
1.6
0.8
-0.8
-1.6
-2.4
-3.2
-4.0
-4.8
-2.4
-1.6
-0.8
0.8
1.6
2.4
3.2
4.0
PC1 (56.0%)
PC2 (25.8%)
= Group 1
= Group 1 subgroup a
= Group 2
= Group 2 subgroup a
= Group 3
= Group 3 subgroup a
= Group 3 subgroup b
= Group 4

Fig 9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300um

Fig 10