Postprint version of the article published in Journal of Archaeological Science: Reports, vol. 42
DOI: 10.1016/j.jasrep.2022.103355

Exploring Roman and Late Roman Common Buff Wares from the rural site of Sa Mesquida (Mallorca, Balearic Islands): continuity of local production?

Miguel Ángel Cau Ontiveros[1, 2, 3, *], Catalina Mas Florit[2], Evanthia Tsantini[2], Leandro Fantuzzi[2,4]

1. Institució Catalana de Recerca i Estudis Avançats (ICREA), Pg. Lluís Companys 23, 08010 Barcelona, Spain
2. Equip de Recerca Arqueològica i Arqueomètrica de la Universitat de Barcelona (ERAAUB), Institut d'Arqueologia de la Universitat de Barcelona (IAUB), Universitat de Barcelona (UB), Facultat de Geografia i Història, Departament d'Història i Arqueologia, c/ Montalegre 6-8, 08001 Barcelona, Spain.
3. Chercheur associé, Centre Camille Jullian,UMR 7299, MMSH, Aix-Marseille Univ, CNRS, Aix-en-Provence, France
4. Universidad de Cádiz, Facultad de Filosofía y Letras, Departamento de Historia, Geografía y Filosofía, Av. Gomez Ulla s/n 11003 Cádiz, Spain

in memoriam, Antoni Vallespir

* Corresponding and senior author: Miguel Ángel Cau Ontiveros, macau@ub.edu

Abstract

In previous studies, the Reference Group (RG) for common wares produced in the 1st and 2nd centuries AD at the kiln found at the Roman rural site of Sa Mesquida (western Mallorca) was established. Recent excavations have revealed that the Roman villa was founded at the beginning of the Augustan period or slightly earlier and that some ceramics found in these foundational layers resemble the ceramic products of the kiln. We also know now that the kiln itself and a large cistern were reused in the Late Roman period (4th and 5th centuries AD) as rubbish dumps, also containing regional (mostly produced in the island of Eivissa, but also others that are macroscopically like the products of the kiln) and other imported common wares. The macroscopic similarities between some of the earlier and later materials generated a series of important questions related to the possibility of a long-lasting local pottery-making tradition at this site or more broadly in western Mallorca. To explore this possibility, 74 common wares from different well-stratified layers were analytically characterized using a combination of Wavelength Dispersive X-Ray Fluorescence and Optical Microscopy by thin-section and both typologically and compositionally compared to the Early Imperial common buff wares produced at the site. The results provided a better understanding of the common wares at the site from a diachronic perspective. The comparison of the new ceramics analyzed from several contexts found at Sa Mesquida with the already established reference group for the common wares showed, in some cases, strong similarities in terms of chemical composition and petrographic fabrics both for early Roman and some Late Roman ceramics. On the other hand, the study also enabled the identification of other non-local groups (primarily products from the neighboring island of Eivissa), providing new information on the provenance and regional distribution of buff wares, a ceramic class whose importance has been often denied.

Keywords: archaeometry, ceramics, Mallorca, Roman pottery, provenance, petrography, reference group, statistical treatment of data

1. **Introduction**

The site of Sa Mesquida is located in Santa Ponça bay in the area of Calvià in the western part of the island of Mallorca in the Balearics (Figure 1a). Archaeological excavations carried out during the 1980s and 1990s (Vallespir et al., 1985-1987; Orfila, 1993; Orfila et al., 1996) uncovered the remains of a rural settlement or villa, including one of the few Roman pottery kilns known in this island (Figure 1b). The kiln and several deposits with discarded materials — including over-fired ceramics— were clear evidence of pottery-making activities at the site (Cau 2008). The typology of the buff common ware included mainly one-handled jars and other small vessels for daily use (Mas Florit et al., 2005; Mas Florit and Cau, 2008). The analytical study of the fine calcareous buff common ware produced at the site allowed the definition of a chemical Reference Group (herein RG) (Tsantini et al., 2004; Cau, 2008).

Recent excavations have demonstrated that the villa was founded perhaps in the Augustan period (approx. 27 BC- AD 14) or slightly earlier at the very end of the Late Republican period (Mas Florit et al., 2015). Subsequent transformations led to structural changes in some floors and rooms of the main building that was destroyed by a fire by the end of the 2nd or early 3rd century. The foundational date of the pottery kiln is unclear, although the archaeological evidence suggests that it was clearly in use during the 1st and 2nd centuries, and it was abandoned with the destruction of the main building. At the end of the 4th century, the kiln was certainly reused as a rubbish dump (Mas Florit et al., in press). In a different sector of the site, a cistern was used also as a rubbish dump with large quantities of ceramics and fauna mainly dated to the Late Roman period and precisely to the first half of the 5th century, but also with some later materials dating to the Byzantine period (post AD 534) (Orfila, 1989; Orfila and Cau, 1994; Buxeda et al., 1998; Cau, 2003).

Most of the early Roman and some Late Roman sherds belonging to common buff wares recovered at the site in recent excavations resemble, from a macroscopic point of view, the previously characterized pottery produced at the site in the 1st and 2nd centuries. In fact, this is a more general problem in several areas of Mallorca where it is often difficult to discriminate common buff wares for the Roman and Late Antique periods and to separate possible local ceramics from ceramic products manufactured in the neighboring island of Eivissa that were widely distributed across Mallorca. This generated a series of questions to be answered. Our aims were to determine whether local common wares were produced only in the 1st and 2nd centuries or also found in earlier periods; whether any of the Late Roman buff common wares were also local products, and if they were not, if these could be classified as ceramics from Eivissa.

To address these questions, some of which could help to understand the timespan of the pottery production at the site, common wares from different well-stratified layers were analytically characterized. Only samples that from a macroscopic level could resemble local or regional products (including ceramics from the neighboring island of Eivissa were included). All those ceramics that considering the macroscopic characteristics and the typology were clear imports were not selected for this study.

The chemical compositions of the ceramics were later compared with the chemical RG previously established for the common buff ware produced at the kiln site. The chemical RG acts as a fingerprint for the composition of common wares produced at the site in the Roman period. The same could be applied for petrographic groups when these are defined at production centers (acting as petrographic control groups), or alternatively, even if defined at consumption centers, when the pottery can be assigned to a more or less specific provenance due to a very distinctive composition, or to a combination of compositional, geological, and archaeological considerations (e.g., Montana 2020). This approach considers the Provenance Postulate (Weigand et al. 1977), but also the concept of non-resolution space or space of uncertainty (Picon, 1973, 1984), and the fact that the concept 'source' has a multidimensional scale (Arnold et al. 1991). Of course, clay sources might present natural variation in the deposits (e.g., Hein et al., 1999, 2004), and the raw materials used in the same production site could also vary over time due to the use of different raw materials and/or to the preparation of different paste recipes (often determined by the need to obtain specific properties depending on the function of the ceramics) (e.g., Buxeda et al., 2003; Hein and Kilikoglou, 2020). However, a positive match between the composition of the newly analyzed materials with that of the RG would help to verify the presence of local products. Nevertheless, for the reasons mentioned before, the composition of the RG does not necessarily have to match other local products. Even if a perfect match is not established, a relative similarity between the composition of the RG and other ceramics could be potentially indicative of a similar nature of the raw materials and paste recipes used, helping to propose the hypothesis of local provenance and to explore regional variation, and to separate regional products from Mallorca from those produced at Eivissa or elsewhere. Of course, if the match is not perfect the interpretation should be cautious due to the possible use of different clays, to the natural variation of the same clay deposits, to different processing of the raw materials, to the possible influence of use and/or postdepositional contaminations and/or alterations, to a combination of several of these factors, or even to the existence of compositional overlapping areas, represented by geographical areas that, although distant, could present raw materials with similar compositions.

2. Materials and methods

Seventy-four common wares from the site of Sa Mesquida were included in this study (Table 1). Most of them have a possible local or regional provenance based on the macroscopic characteristics of the fabrics and on the typology. Most of the selected samples came from the Late Roman contexts of a cistern used as a rubbish dump between the 5th and 7th century (labeled MC) (n=57). Other Late Roman ceramics were selected from the late 4th/early 5th century rubbish dump that was infilling the former kiln (some of the labeled as MCFN) (n=8). The sampling was completed with three samples from layers related to the initial construction of the Roman villa, two from early Roman layers, and four from the abandonment layers of the kiln dated to the end of the 2nd or early 3rd century (all these samples labeled also as MCFN). The number of samples related to the initial phases of the site was limited due to the low numbers of possible local/regional common wares of those chronologies found in layers excavated in the main building of the settlement. This scarcity is also related to the nature of the layers that were mainly related to building activity.

In a second step, the 68 samples for which we had chemical concentrations were compared to the compositional Reference Group (n=54) established using ceramics from various deposits of discarded materials related to the Roman Imperial kiln found at the site (labeled MCF: Table 1) (Tsantini et al., 2004).

The selected ceramic samples were analyzed by using wavelength dispersive X-ray fluorescence (WD-XRF) spectroscopy for their chemical characterization and optical microscopy (OM) by thin section analysis for their petrographic-mineralogical study. Due to weight constraints, not all sherds were analyzed with all techniques (see Table 1).

The WD-XRF chemical analysis was carried out using a Phillips PW 2400 spectrometer with a Rh excitation source. Powdered and homogenized specimens were dried at 100 °C for 24 hours.

Major and minor elements were determined by preparing duplicates of fused beads using 0.3 g of a specimen in an alkaline fusion with lithium tetraborate (1/20 solution). Trace elements and Na_2O were determined through pressed powder pellets, made from 5 g of specimen mixed with Elvacite agglutinating, placed over boric acid in an aluminium capsule and pressed for 60 s at 200 kN. The concentrations of 29 major, minor, and trace elements were obtained: Fe_2O_3 (as total Fe), Al_2O_3, MnO, P_2O_5, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2, Ba, Rb, Mo, Th, Nb, Pb, Zr, Y, Sr, Sn, Ce, Co, Ga, V, Zn, W, Cu, Ni, and Cr. A calibration line based on 60 International Geological Standards was used for quantifying the elemental concentrations. The loss on ignition (LOI) was estimated by firing 0.3 g of a dried specimen at 950 °C for 3 h. For the multivariate statistical treatment of the chemical data, the chemical concentrations were transformed into additive log-ratios (alr), following the methodology proposed by Aitchison (1986, 1992) and Buxeda (1999). At the same time, we used the log-ratio transformation to scale the data avoiding possible perturbation problems that might be introduced by elemental alterations that could not be detected.

The OM petrographic-mineralogical analysis of thin sections was carried out using an Olympus BX41 polarizing microscope, working with a magnification between 20X and 200X. The identified fabrics were analyzed following the methodology by Whitbread (1989, 1995) and Quinn (2013).

3. Geological background and clays of the area

The island of Mallorca, located in the western Mediterranean Sea, constitutes the most important emerged segment of the so-called Balearic Promontory, which is the northeastern prolongation of the external zones of the Betic System (southern and eastern Iberian Peninsula) into the Mediterranean Sea. This orogenic promontory consists of Paleozoic to Middle Miocene materials deformed in the thrust and fold system during the Late Oligocene–Middle Miocene (Sabat et al., 1988; Gelabert et al., 1992; Acosta et al., 2003).

The Roman *villa* of Sa Mesquida, in western Mallorca, lies in an area generally dominated by sedimentary geology, with Quaternary deposits —mainly aeolian and beach sands, siltstones, and clays— lying over a calcarenitic basement (ITGE 1992a, 1992b) (Figure 2). The site was very close to an ancient lagoon known as el Prat de Santa Ponça, which dried out in the 19th century. The closest hills are mostly formed by Jurassic limestones, dolomites, marls, and sandstones. Towards the south, widespread outcrops of siltstones, red clays, and aeolianites (*marès*) are also present. The area located to the north of the site is dominated by large outcrops of Tertiary conglomerates, clays, silts, and limestones (ITGE 1992a, 1992b). In summary, the geology of the zone of Santa Ponça —as well as of the wider region of the Calvià peninsula— is mostly sedimentary, with a dominance of carbonate deposits (Figure 2).

Different clays have been studied in the area within an extensive research program focused on pre and protohistoric pottery and their possible raw materials (e.g., Albero and García Amengual, 2010; Albero, 2011, 2017; Albero and Mateu, 2012). Some of the collected clays from Cretaceous, Tertiary, Pleistocene, and Holocene deposits were subjected to the study of their physical properties and composition including a micropaleontological approach (Albero and Mateu, 2017). While a full comparison is outside the scope of this paper, we are particularly interested in the clay from the location called 'Es Comellar de sa Terra des Gerrers', a Tertiary clay with excellent properties (Albero and García Roselló, 2008; Albero, 2011; García Roselló and Albero, 2011) and an abundant quantity of microfossils. Possible long-term use of this raw material source has been suggested (Antoni Vallespir, oral communication; Albero, 2017; Albero and Mateu, 2012). The name place in Catalan, particularly in Mallorcan dialect, is already extremely relevant as it can be translated approximately as 'the valley of the earth (or clay) of the water-jars potters'. This denotes that the outcrop was used in historical times as a raw material source and more specifically for the calcareous clays used to manufacture the typical Mallorcan wheel-made water jars in buff ware fabrics. The outcrop is 500 m away from the important Iron Age site of Puig de Sa Morisca with an important pottery-making tradition (e.g., Albero, 2011, Albero and Cau, 2016), and not far (approx. 1 km) from the Roman villa of Sa Mesquida.

4. Results

4.1. Chemical Results

The chemical study was carried out in two different phases. First, we explored the chemical composition of the 68 samples for which we had chemical data (labels MC and MCFN, see Table 1). Later, those were compared to the RG established for the common wares produced at the kiln found at the site (n=54, labels MCF) (Table 1) (Tsantini et al., 2004). It was important to verify if the common buff wares found at the earlier layers of the main building could belong to the already established RG of the kiln. This was relevant as it could demonstrate that the ceramic production at the site started earlier than previously thought and was active probably since the foundation of the Roman *villa*. Second, it was important to explore whether some of the Late Roman ceramics found at the site could be local products or from Eivissa or elsewhere in the region. Since the kiln was already destroyed in the 2nd or 3rd century AD, we knew on archaeological grounds that the Late Roman ceramics were not products of that kiln, and that the composition of the RG might not match the new ceramics under analysis. Yet, we wanted to explore if there were enough compositional similarities that could suggest the existence of possible local products denoting a long-lasting local/regional production of common wares. To do so, we had to examine to what extent the composition of the new sampled ceramics could be like the kiln products. The raw chemical composition of a total of 131 samples, including the pottery used to establish the RG and the north-African common wares included as comparative material, is presented in Table 2.

Chemical composition

To explore the chemical variability of the dataset, we first calculated the compositional variation matrix (CVM) (Buxeda and Kilikoglou, 2003) for the 68 samples, without including yet the samples of the RG and excluding certain elements that could falsely affect the variability. Those elements, generally, were not considered during the whole statistical treatment. Mo and Sn were excluded due to low concentrations and analytical imprecisions (both are lower than their regression limits in our samples). Co and W were not considered due to possible contaminations during sample preparation (a tungsten carbide cell was used for powdering). The total variation (vt) according to the CVM is equal to 1.2854, which is too high for a monogenic sample (homogenous population). The variability that each of the chemical elements introduces in the dataset is represented in the line plot of Figure 3a.

The most variable element is CaO; nonetheless, its variability (and that of the geochemically related element Sr) can be explained by the calcareous nature of the analyzed materials (Table 2). In several works dealing with the geochemical variation of calcareous clays in the same geological source, a large standard deviation in CaO has been observed (e.g., Hein et al., 2004a, 2004b; Belfiore et. al., 2007; Hein and Kilikoglou, 2020). Likewise, the presence of secondary calcite can also contribute to the CaO variability (e.g., Buxeda and Cau, 1995; Cau et al., 2002). On the other hand, the variation in Cu seems random, oscillating between 4 and 31 ppm. The variability of Pb is clearly influenced by the presence of some samples with exceptionally low contents and, conversely, the individual MC1109 with 114 ppm in normalized data (which could be indicative of contamination). The variation in Na_2O is certainly influenced by the relatively high concentrations of this element found in samples MCFN58, MCFN60, MCFN70, MCFN74, MCFN79, MC1100, and MC1110 due to the presence of analcime ($Na_2AlSi_2O_6 \cdot H_2O$), as confirmed by complementary mineralogical analysis carried out through X-ray powder diffraction on these samples (Figure 4). Analcime constitutes a secondary mineral phase precipitating due to post-depositional alteration and/or contamination processes (e.g., Picon, 1991; Buxeda et al., 2001, Schwedt et al., 2006; Maritan, 2020) that affects the data with an enrichment of Na_2O, and potential depletion of K_2O and Rb. Finally, MnO is generally low except for two samples (MC1033 and MC1047) that exhibit much higher content. The total variation removing all the elements mentioned above (CaO, Sr, P_2O_5, MnO, K_2O Na_2O, Pb, Rb and Cu) drops down to 0.4156, which is much lower yet still high for a homogenous dataset.

To summarize the chemical results, a cluster analysis was performed using additive logratio (alr) transformed data for a subcomposition that excludes those elements mentioned above and that could cause possible perturbations. The cluster tree reveals the presence of three major groups (G1, G2, and G3) and a series of loners (Figure 3b). The chemical differences between the three groups (and the loners) can also be observed by performing a principal component analysis on the same alr transformed subcomposition as the cluster analysis (Figure 5). The statistical treatment was performed excluding: Pb, P_2O_5, Cu, MnO, Na_2O, K_2O and Rb, and using Ga as divisor in the logratio transformation.

In short, the chemistry, not only the statistical treatment but also de detailed examination of the normalized chemical data, reveals the presence of at least four major groups:

- Group 1 (G1; n= 10) includes the samples labeled as MCFN (MCFN046, 54, 55, 56, 58, 59, 60, 61, 62 and 64), except for MCFN057 (Figure 3b), which is much less calcareous and has important differences in almost all trace elements (Table 2), matching better with Group 3 (G3) composed by Ebusitan materials (manufactured in the neighboring island of Eivissa). All these samples come from early Roman layers of the excavation. The vt calculated for G1, including all elements except for P_2O_5, is 0.4168. Nevertheless, some other elements might be contaminated and/or have some accuracy problems (Mn, Pb, Cu), and we certainly know that in this set of samples MCFN58 and MCFN60 are samples with analcime precipitation. After recalculating the CVM without P_2O_5, MnO, Na_2O, K_2O, Pb, and Cu the resulting vt is equal to 0.2292, suggesting a monogenic group. The main variations between the individuals are now marked by the calcareous content (CaO and Sr) and minor differences in some trace elements such as Y or Zr (Table 2).

- Group 2 (G2; n= 10) is clearly formed by a series of Late Roman ceramics (MC1001, 1004, 1005, 1007, 1008, 1018, 1022, 1026, 1096, and 1110) (Table 2), with some samples that behave as outliers but clearly related to the group 1025 and 1086, 1100 and 1023. The calculation of the CVM considering all these samples after removing P_2O_5, MnO, Na_2O, K_2O, Rb (MC1100 has analcime), Pb, and Cu provides a vt value of 0.1321, indicating a monogenic character. The results indicate a chemical proximity between G1 and G2. Those two groups are the most calcareous ones in the dataset and show also important similarities in trace elements (Table 2). This cluster (G2) is geochemically consistent with that characterized as Eb-01 in previous studies (Buxeda et al., 2005).

- **Group 3** (G3; n= 29) is the major group in the dataset and includes the following samples: MC1000, 1002, 1003, 1006, 1009, 1010, 1011, 1012, 1013, 1014, 1015, 1016, 1017, 1024, 1027, 1028, 1029, 1082, 1089, 1091, 1093, 1098, 1102, 1103, 1106, 1107, 1108, 1112, and 1113. Most of the sherds in G3 have been previously identified as groups Eb-02, Eb-03, Eb-04 and Eb-05 for which a provenance in Eivissa has been proposed (Buxeda et al., 2005). The subgroups (that can be also observed in the cluster tree) are formed due mainly to relative differences in CaO wt%. Nevertheless, the vt value is 0.3985, suggesting a monogenic sample, and it is even lower (0.1719) without considering P_2O_5, MnO, Na_2O, K_2O (we removed Na_2O and K_2O because there is analcime in at least in sample MC1010), Rb and Pb and Cu.

- **Group 4** (G4; n=5) is formed by samples MC1019, MC1021, MC1036, MC1037, and MC1109, with MC1090 probably forming part of the group, but with some difference, and MC1020 somehow related. It is a small group of what on archaeological grounds have been considered Ebusitan products, but with some differences with respect to Group G3, particularly a relatively lower content of CaO. Sample MC1036 presents analcime, for that if we calculate the CVM without P_2O_5, Pb and Na_2O, K_2O, and Rb the vt value is equal to 0.6503, dropping to 0.0763 removing P_2O_5, MnO, Na_2O, Rb and Pb and Cu.

There are a few samples that exhibit some chemical differences and enter in the groups already defined. These outliers/loners can be clearly observed in the dendrograms and in the PCA scatter plot of Figure 5 (see Table 2 as well). Considering the dendrogram of Figure 3b, in the right branch the pairs of samples 1025 and 1086, and 1023 and 1100, with 1097 are somehow outliers to group G2. MC1083 is compositionally somehow related to G1 yet it shows less Al_2O_3, SiO_2, Zr, Y, Ce and Ni, and slightly more Cr. MC1084 and MC1114 are characterised by lower Fe_2O_5, Al_2O_3, Nb, Y and Ga, and slightly higher Zr. Those differences make them dissimilar to both G1 and G2, although somehow related. On the other side of the three, samples MC1061 and MC1099 are similar and tend to gather. Even though some of the chemical concentrations assimilate them to the Ebusitan products, there are significant differences in some major and trace elements such as higher Fe_2O_5, Al_2O_3 and TiO_2 and slightly higher Ga, Ni, and Cr that clearly indicate those are not G3. Samples1090 and 1020, could be outliers of G4. MCFN057 seems related to the Ebusitan productions, yet it is more calcareous and have less

Fe_2O_3, Al_2O_3, Th, V, Zn, and Cr that makes it unique in its composition within the dataset. Finally, MC1081 outstand because of their slightly higher values in Ni, Nb, Fe_2O_3 Na_2O and lower values in K_2O, Rb and Zn. Some of these samples can be considered outliers of some of the groups defined, but other might represent other products not well-represented in the sample, and although in macroscopic terms they resemble the local/regional materials some could be even imported.

The comparison with the chemical Reference Group

A similar statistical treatment was followed by comparing the new samples with the RG for the common buff wares produced at the site (labeled as MCF in Table 2) (Tsantini et al., 2004). The total variation now is 1.5990. The line plot in Figure 6a shows no differences in variability from the previous results. Without Pb, P_2O_5, Cu, MnO, Na_2O, K_2O, and Rb the total variation drops down to 0.8794. In Figure 6b, a cluster tree resulting from the same statistical treatment as in Figure 3b, and excluding the above-mentioned elements, is presented. The group G1 seems to relate to the RG of the kiln, with similar chemical compositions, but it does not perfectly match. To evaluate the chemical variation, we calculated the CVM only for that subset (RG+G1), first excluding P_2O_5, Pb, MnO, and Cu, and later excluding also Na_2O, K_2O, and Rb due to the presence of analcime, obtaining vt values of 0.3733 and 0.1137, respectively. Therefore, it is very likely that they can be considered as monogenic group and we can sustain that the ceramics forming G1 were very likely produced at the site.

Groups G2, G3, and G4 are preserved although separated in a different manner (Figure 6b). The scatterplot of the PCA analysis of the first and third principal components shows two different chemical tendencies (Figure 7). The biplot with the first and second components is not presented here, as both are dominated by the variability in CaO and no further chemical distinctions can be made. Both cluster analysis and PCA show that RG+G1 and G2 tend to cluster, while both G3 and G4 are separated from the rest (Figures 6b and 7).

As a synthesis of the chemical groups defined, Table 3 shows the mean and standard deviation for the RG and for each of the four main groups, including also the mean and standard deviation for RG and G1 separately to show the small differences in certain elements.

4.2. **Petrographic-mineralogical results**

Thin-section OM provided further information on the petrographic and mineralogical characterization of the materials. However, the 49 samples of common wares analyzed through this technique (Table 1) showed fine-grained fabrics (Figure 8) composed of a similar range of sedimentary inclusions, making the differentiation of fabrics difficult.

Inclusions in the coarse fraction (>0.10 mm) are absent or scarce, and —when present— they may consist of limestone, calcareous fossils, iron-rich argillaceous inclusions (clay pellets and/or iron nodules), quartz, and sandstone. The fine fraction (0.10-0.01 mm) is always predominant, and it is composed of quartz, micas (mostly muscovite), carbonate inclusions and iron oxides/opaques, in variable amounts. Porosity is always low and generally consists of small mesovesicles and mesovughs. The matrix is usually calcareous, ranging from yellowish-brown or greenish-brown in color under plane polarized light (PPL).

Despite the general similarities in fabrics among all the ceramic samples, gradual variations in the relative frequencies of the components of the fine fraction were observed, as well as in the grain-size distribution of the inclusions, from samples with predominant silty inclusions to others in which both silt and very fine sand are dominant.

Petrography of the reference group

The samples that formed the reference group (RG) of the Early Roman Imperial kiln of Sa Mesquida (MCF001, MCF012, MCF018, MCF007, MCF008, MCF017, and MCF022) were particularly rich in carbonate inclusions, both calcite (micrite mainly) and calcareous microfossils (mostly foraminifera); these were predominantly fine-grained (Figure 8a-b), from silt to very fine sand, but included also few to common fine sand, and rare coarser inclusions, up to 1.20 mm. Quartz particles are common, but predominantly in the silty fraction (<0.06 mm), whereas very fine sand grains are scarce. Very few micas were present in this fabric, with mode <0.10 mm. The matrix is either yellowish-brown, optically active (e.g., MCF001, MCF012, and MCF018), or greenish-brown, optically inactive and with signs of having been fired at high temperatures (MCF007, MCF008, MCF017, and MCF022) (Figure 8a-b). In these higher-fired samples, reacted carbonate inclusions and secondary calcite are observed; this can be related to the presence of calcite peaks in the XRD patterns of these samples. In any case, most of this secondary calcite could be interpreted as only partly allochthonous, where Ca derives from the ceramic itself rather than from the environment (Cau et al., 2002), since it is observed in thin section in the form of micritic clots, reaction rims, and some patches. Ghosts of both calcite and microfossils (Fabbri et al., 2014; Privitera et al., 2015) were found as well. Even in these high-fired samples, remains of not fully decomposed carbonate inclusions can be found. In summary, the analysis suggested that the presence of completely allochthonous secondary calcite (Cau et al., 2002) was not significant in these samples; this corresponds well with the low relative standard deviation value for CaO in this RG from the kiln (4%).

The rest of the samples from Sa Mesquida

Apart from the RG from the kiln, the ceramic samples from other layers that, according to the chemical analysis, were similar in composition to the RG, showed, in most cases, similar fabrics in thin section (Figure 8). These include samples from the contexts dated to the foundational period of the *villa* (MCFN064; Figure 8c), the late 2nd/early 3rd century (MCFN060, MCFN061, and MCFN062; Figure 8d), and the late 4th to early 5th century AD (MCFN054, MCFN055, MCFN056, MCFN058, and MCFN059; Figure 8e) and some of the 5th-7th century sherds (MC1001, MC1005, MC1007, MC1008, and MC1022; Figure 8f-g). However, some of these samples, particularly those from the late 2nd/early 3rd century and the majority of those from the 5th-7th century AD, showed slightly different textures, with a slightly higher frequency of quartz in the very fine sand fraction, even if silty quartz is still dominant. Moreover, those from the late 2nd/early 3rd century contained occasional, very rare coarse fragments (0.80 mm) of crystalline rocks composed of quartz and feldspar. In any case, all the other characteristics of the fabrics are like the RG, so these minor variations may suggest the use of slightly different raw clays in these periods, perhaps from nearby sources or, less likely, differences in processing. In summary, the petrographic analysis supports the hypothesis of local provenance for these samples or at least a provenance in the same broad geological area in western Mallorca. Samples MCFN083, MCFN088, and MCFN089, for which we only have thin sections, are linked to the local products in terms of their petrographic composition, as is also the case of MCFN084, although with a coarser texture.

Conversely, 16 other ceramic samples analyzed through OM (all of them from the Late Roman context of the cistern used as a rubbish dump), which were similar in chemical composition to ceramic products from Eivissa —group G3 and group G4 (Figure 4) / groups Eb-02 to Eb-05 (Buxeda et al., 2005)—, showed in fact different fabrics in thin section (Figure 8h-i). These are usually richer in very fine sand grains of quartz and with relatively lower frequencies of carbonate inclusions compared to the local fabrics from Sa Mesquida, and in many cases also with higher frequencies of micas (muscovite). The clay matrix also tends to present a more reddish-brown color in PPL. Both the aspect of the matrix and the relative frequencies of inclusions suggest a lower calcareous composition in these fabrics compared with the RG from Sa Mesquida; this is consistent with the lower CaO wt% found in the former, while the higher SiO_2 wt% should be related to the higher abundance of very fine sandy quartz in these fabrics.

In general, the fabrics observed in these samples are the same as those found in other Late Roman common wares from Eivissa analyzed so far (e.g., Cau et al., 2019).

5. Discussion

The comparison between the new samples from several ceramic contexts found at Sa Mesquida with the reference group (RG) showed, in some cases, strong similarities in terms of chemical composition and in petrographic fabrics. The few new samples analyzed from the early Roman contexts of the main building of this rural site, contained in group G1, seem to match relatively well with the RG (except for sample MCFN057 for which a provenance in Eivissa can be suggested). Some of the sherds come from layers of Phase I of the main building suggesting that the kiln was probably active since the foundation of the *villa.* The typology of the materials (Figure 9) matches also with the types defined as produced in Sa Mesquida consisting mainly of jars with different forms.

The materials recovered once the kiln was used as a rubbish dump in the late 4th - early 5th centuries AD (Figure 9) form also part of group G1 and show also compositional similarities with the earlier materials and the RG. Despite some textural differences, these materials could be local or nearby products. The fact that some common buff ware samples from Late Roman contexts are very similar to the earlier materials could be indicative of continuity of local ceramic production in the Late Roman period, although this kiln was already destroyed by the end of the 2nd or early 3rd century AD.

The ceramic materials from the 5th-7th centuries AD found at the cistern used as a rubbish dump show two main tendencies. The samples forming chemical group G2 exhibit broad compositional similarities to the Early Roman materials and to the late 4th/early 5th centuries ceramics from the rubbish dump of the kiln. The forms included in this group are primarily bowls with spouts and large bowls that are well-represented in the Ebusitan typology (Figure 10). In fact, the samples of this group were classified in previous studies as group Eb-01 with a supposed provenance in the island of Eivissa (Buxeda et al., 2005). Considering this new analysis and the compositional similarities with the reference group and the early Roman materials, the interpretation can be twofold. Group G2 could be interpreted as local or nearby regional ceramics, perhaps produced using slightly different clay deposits that could have been differentially exploited over time. However, we should not forget the possible existence of overlapping areas, that is, regions with similar clayey materials that could result in similar products in compositional terms. Despite of the similarities with the reference group and the materials, G2 could also be products from Eivissa that have not been identified yet in other sites and that are compositionally close to the products manufactured at Sa Mesquida or more broadly in the area. In this case, the low number of regional common wares and clayey materials analyzed so far does not allow for stronger conclusions, and the interpretation must be cautious. If a regional provenance in western Mallorca is possible, this would mean that forms in "Ebusitan style" were produced also in Mallorca, a hypothesis that we have already proposed in the past (Buxeda et al., 2005).

On the other hand, the samples contained in group G3, which is clearly distinct from the local materials, were previously classified as Groups Eb-02 to Eb-05 (Buxeda et al., 2005) and could well correspond to what we consider ceramic products from the island of Eivissa. The samples represented in this group, forming several subgroups, are clearly typical Ebusitan types (Figure 11) including some sherds with the so-called ‘monolinear’ decoration. So, a provenance from the island of Eivissa can be accepted for these materials. This seems to be the case also for G4 which might represent products from Eivissa but slightly different in terms of composition, mainly due to its relative lower CaO content.

Despite the evidence of pottery-making activities at the site in the Early Roman period and a possible continuation of the ceramic tradition over time, most of the common wares analyzed dated to the 5th-7th centuries are common wares produced in Eivissa or elsewhere. It is worth mentioning that, of course fine wares, and amphorae, but also other common and cooking wares from the same 5th-7th century contexts —not included in this study— were imported from other regions of the Mediterranean as demonstrated by previous analyses and archaeological considerations (Cau, 2003; Buxeda et al., 2005). Therefore, the results suggest that even if a small percentage could have been locally produced at the site or their surroundings, the utilitarian pottery consumed at this rural settlement in the Late Roman period and more broadly in Late Antiquity was generally allochthonous, arriving from different markets outside the island. However, this paper is focused on the possible local or regional wares and not on the imported materials.

The chemical and petrographic results suggest that a calcareous clayey raw material, rich in fine carbonate inclusions (silt to very fine sand) and silty quartz, was used for pottery making in Sa Mesquida, with no tempering. This is clear for the Roman and some of the Late Roman common buff wares. The minero-petrographic composition of the ceramics from the local reference group, and of those for which the chemical analysis suggests a local provenance, is compatible with that of the sedimentary deposits in the surroundings of the site (Tsantini et al., 2004) (Figure 2). The clay of Es Comellar des Gerrers, characterized by Albero and Mateu (2012) as containing large numbers of microfossils (also abundant in the locally produced ceramics), could have been used in Sa Mesquida, but this needs a closer comparison with the already analyzed clays and a further exploration of other possible sources to determine the exact source (or sources) that was exploited. Approximately similar raw materials, with slight differences, were also used for manufacturing the Late Roman common wares in group G2. In this sense it is possible to suggest a provenance in Mallorca, but we cannot discard the possibility of an origin in Eivissa with the evidence available thus far.

6. Conclusions

The combined chemical and minero-petrographic analysis of the pottery provided evidence for distinguishing between local (or nearby) products from Sa Mesquida and regional wares from other Balearic areas (notably Eivissa). The results of the OM analysis showed that despite the broad petrographic similarities, minor variations in terms of grain-size distribution and relative frequencies of the inclusions, as well as in the clay matrix, allowed for the identification of a series of fabrics. Therefore, it was possible to find differences both in chemical composition and in petrographic fabric between the ceramic samples with a local or maybe more broadly a western Mallorcan provenance and those with a wider regional provenance from other areas within Mallorca or as inter-island distribution (materials from Eivissa), even if the differentiation based on thin-section petrography is not always straightforward.

The obtained results provide analytical evidence for the archaeological hypothesis of the occurrence of a long-term tradition of pottery production at the area of Sa Mesquida or, more generally, in western Mallorca, focused on the manufacturing of various forms of buff common wares. Despite minor textural variations observed in thin section, the combined petrographic and chemical data suggest the use of similar sources of raw materials for ceramic production from the Early Roman to the Late Roman periods. Moreover, technical similarities regarding raw material processing and paste preparation —basically the use of fine-grained calcareous clayey sediments with no evident added temper— indicate a certain degree of continuity in at least some of the technological choices made by the potters over time. Considering the analytical results, it seems plausible that the Roman *uilla* produced pottery from its foundation surely until the destruction of the kiln at the end of the second century or beginning of the 3rd century AD, and probably until the late 4th or early 5th century —although in a different kiln and with some differences in the procurement strategies or preparation of the raw materials. The main problem is accepting the possibility of the continuity of the pottery production in Late Antiquity on the site or more broadly speaking in western Mallorca of common buff wares that compositionally resemble the local materials but that in typological terms are like Ebusitan types. This would not be strange considering the large quantities of Ebusitan materials arriving traditionally in Mallorca, and that could have been imitated. However, although group G2 certainly has compositional similarities to the materials produced at the workshop, we need to be cautious with ascribing it a local provenance, as it could also be an Ebusitan group not yet characterized in other sites across the Balearics and made from clays similar to those used by the potters in Sa Mesquida.

In any case, the presence of local products is not to deny the importance of regional wares coming from other parts of the Balearics (notably from Eivissa) and elsewhere in the Mediterranean (imports were not included in this study) as a clear sign of the strategic role that the Balearics had in the trade routes of the western Mediterranean. In this sense, the Roman *villa* of Sa Mesquida was well connected to Mediterranean trade dynamics.

The Roman and Late Roman/Late Antique common buff wares produced in the Balearics are, both from an archaeological and an analytical point of view, a complex subject that deserves attention to define better production areas and to clarify intra-island and inter-island production and exchange. The future research should include the analysis of more ceramics from different sites —both consumption and production centers (although so far very few kiln sites are known)— across the islands of the archipelago. In addition, the progressive characterization of potential clayey raw materials, especially if kiln sites are found, complemented with a detailed study of microfossils, could be also of benefit to fully clarify the common regional wares produced in the Balearics in the Roman and Late Antique periods.

Acknowledgements

This contribution is part of the results of the project *Archaeology, Remote Sensing, and Archaeometry: A multidisciplinary approach to landscape and ceramics from the Roman to the Medieval period in Mallorca (Balearic Islands)* (ARCHREMOTELANDS) (HAR2017-83335-P), PI: Miguel Ángel Cau Ontiveros, funded by the Ministerio de Ciencia, Innovación y Universidades, with contribution from the European Regional Development Fund from the European Commission, and benefits from the synergies created with the project *Caracterización arqueométrica de cerámicas tardoantiguas y de época islámica de la ciudad romana de Pollentia (Alcúdia, Mallorca)* funded by Fundación PALARQ. The initial sampling and analytical work were performed within the framework of the project *Late Roman Pottery in the Western Mediterranean: exploring regional and global trade networks through experimental sciences (LRPWESTMED)* (ref. HAR2013-45874-P), PI: Miguel Ángel Cau Ontiveros. This is also part of the activities of the Equip de Recerca Arqueològica i Arqueomètrica de la Universitat de Barcelona (ERAAUB), Consolidated Group (2017 SGR 1043), thanks to the

support of the Comissionat per a Universitats i Recerca del DIUE de la Generalitat de Catalunya. The work of C. Mas Florit was possible thanks to a Juan de la Cierva-Incorporación and that of L. Fantuzzi thanks to a Juan de la Cierva-Formación grants from the Ministerio de Ciencia, Innovación y Universidades from the Spanish Goverment.
This work is dedicated to our friend Antoni Vallespir who recently passed away and who shared with us his knowledge of the Santa Ponça area, including the location of the clays of the Es Comellar de sa Terra des Gerrers. We would like to thank the editors and reviewers for all their comments and suggestions that have certainly helped to improve the final version of this manuscript, and to Bailey Franzoi, University of Michigan, for the revision of the English manuscript.

References

Acosta, J., Canals, M., López-Martínez, J., Muñoz, A., Herranz, P. Urgeles, R. Palomo, C., Casamor, J.L., 2003. The Balearic Promontory geomorphology (western Mediterranean): morphostructure and active processes. Geomorphology. 49, 177-204.

Aitchison, J. 1986. The statistical analysis of compositional data. Chapman and Hall, London.

Aitchison, J. 1992. On criteria for Measures of Compositional Difference, Math. Geol. 24, 365-379.

Albero, D. 2011. Caracterización tecnológica, social y adaptación funcional de cerámicas prehistóricas en el oeste y sureste de Mallorca (1700-50 BC). PhD, University of Granada, Spain, https://digibug.ugr.es/handle/10481/18426.

Albero, D. 2017. The Times They Were a-Changing: Cultural Encounters, Social Transformations and Technological Change in Iron Age Hand-made Pottery from Mallorca (Spain). *Journal of Mediterranean Archaeology* 30 (1), 105-131.

Albero Santacreu, D., Cau Ontiveros, M. Á. 2017. Technological Choices in Hand- Made Indigenous Pottery from Western Mallorca (Balearic Islands, Spain) (C. 1200–75 bc): An Archaeometric Approach. *Archaeometry* 59 (4), 642-666.

Albero, D., García Amengual, E. 2010. Estrategias de gestión de los recursos arcillosos en la prehistoria de Mallorca (1000–123 AC): usos cerámicos y no cerámicos, in: Saiz, M.E., López, R.M., Cano A., Calvo, J.C. (Eds.), Actas del VIII Congreso Ibérico de Arqueometría, Seminario de Arqueología y Etnología Turolense, Teruel, Spain, pp. 317–325.

Albero, D; García Roselló, J., 2008. Áreas fuente de arcilla: Una propuesta para su studio, in: A. Morgado, J. Baena, D. García (Eds.), II Congreso Internacional de Arqueología Experimental, Ronda, Málaga, Spain, pp. 95.

Albero, D. and Mateu, G. 2012. Raw Materials and Pottery Production at the Late Bronze and Iron Age Site of Puig de Sa Morisca, Mallorca, Spain. *Geoarchaeology*, 27, 285-299.

Arnold, D. E., Neff, H., Bishop, R. L. 1991. Compositional analysis and “sources” of pottery: an ethnoarcheological approach. *American anthropologist*, *93*(1), 70-90.

Belfiore C.M., Day, P.M., Hein, A., Kilikoglou, V., La Rosa V, Mazzoleni P, Pezzino A., 2007. Petrographic and chemical characterization of pottery production of the Late Minoan I kiln at Haghia Triada, Crete. Archaeometry 49 (4), 621–653.

Bieber, Jr. A.M., Brooks, D.W., Harbottle, G., Sayre, E., 1976. Application of multivariate techniques to analytical data, *Archeometry* 18 (1), 59-74.

Buxeda, J., 1999. Alteration and contamination of archaeological ceramics: the perturbation problem. J. of Arch. Sci. 26, 295–313.

Buxeda, J., Cau Ontiveros, M. Á., 1995. Identificación y significación de la calcita secundaria en cerámicas arqueológicas. Complutum 6, 293-309.

Buxeda, J., Cau, M. A., 2004. Annex I. Caracterització arqueomètrica de les produccions tardanes d'Iluro. Laietània 15, 449-498.

Buxeda, J., Cau, M.A. and Kilikoglou, V. (2003), Chemical variability in clays and pottery from a traditional cooking pot production village: Testing assumptions in Pereruela, Archaeometry 45 (1), 1-17.

Buxeda, J., Cau, M.A., Gurt, J.M., Tsantini, E., Rauret, A.M., 2005. Late Roman coarse and cooking wares from the Balearic Islands in Late Antiquity, in: Gurt, J.M., Buxeda, J., Cau, M.A. (Eds.), LRCW 1: Late Roman Coarse Wares, Cooking Wares and Amphorae in the Mediterranean. Archaeology and archaeometry. Archaeopress, Oxford, pp. 223–254.

Buxeda, J., Cau, M.A., Loschi, A.G., Medici, A. (1998), Caracterización arqueométrica de las ánforas tardías de la cisterna de Sa Mesquida (Sta. Ponça, Calvià, Mallorca). Resultados preliminares, in: El vi a l'Antiguitat: economia, producció i comerç al Mediterrani ccidental, Monografies Badalonines. Museu de Badalona, Badalona, pp. 530-542.

Buxeda, J., Kilikoglou, V., Day, P. M., 2001. Chemical and mineralogical alteration of ceramics from a Late Bronze Age kiln at Kommos, Crete: the effect on the formation of a reference group. Archaeometry 43, 349–71.

Cau, M.A. (Ed.), 2008. Estudi arqueològic i caracterització arqueomètrica de la ceràmica comuna romana del forn de Sa Mesquida (Calvià, Mallorca), El Tall 16, Palma de Mallorca.

Cau, M.A., Day, P.M., Montana, G., 2002. Secondary calcite in archaeological ceramics: Evaluation of alteration and contamination processes by thin section study, in: Kilikoglou, V., Hein, A., Maniatis, Y. (Eds.), Modern trends in scientific studies on ancient ceramics: papers presented at the 5th European Meeting on Ancient Ceramics, Athens 1999. Archaeopress, Oxford, pp. 9-18.

Cau, M.A., Tsantini, E., Fantuzzi, L., Ramon, J., 2019. Archaeometric characterization of Late Antique pottery from the rural site of Ses Païsses de Cala d'Hort (Eivissa, Balearic Islands, Spain). Archaeol Anthropol Sci 11: 627–649.

Fabbri, B., Gualtieri, S., Shoval, S., 2014. The presence of calcite in archeological ceramics. Journal of the European Ceramic Society 34: 1899–1911.

García Rosselló, J., Albero, D., 2011. Áreas fuentes de arcilla. Identificación y análisis de plasticidad, in Morgado, A., Baena, J., García, D. (Eds.), La investigación experimental aplicada a la arqueología. Granada: Universidad de Granada, pp. 385-391.

Gelabert, B., Sabat, E., Rodriguez-Perea, A., 1992. A structural outline of the Serra de Tramuntana of Mallorca (Balearic Islands). Tectonophysics 203, 167-183.

Hein A., Day P.M., Quinn P.S., Kilikoglou V., 2004. The geochemical diversity of Neogene clay deposits in Crete and its implications for provenance studies of Minoan pottery. Archaeometry 46, 357-384.

Hein, A., Day, P. M., Cau Ontiveros, M. A., Kilikoglou, V., 2004. Red clays from Central and Eastern Crete: geochemical and mineralogical properties in view of provenance studies on ancient ceramics. *Applied Clay Science*, 24(3-4), 245-255.

Hein A., Kilikoglou V., 2017, Compositional variability of archaeological ceramics in the eastern Mediterranean and implications for the design of provenance studies. J. of Arch. Sci Rep. 16, 564–572.

Hein, A., Kilikoglou, V., 2020. Ceramic raw materials: how to recognize them and locate the supply basins: chemistry. Archaeological and Anthropological Sciences, 12 (8), 1-17.

Hein A., Kilikoglou V., 2020, Ceramic raw materials: how to recognize them and locate the supply basins: chemistry. Archaeological and Anthropological Sciences. 12, 180.

Hein, A., Maran, J., Mommsen, H., 1999. Element concentration distributions and most discriminating elements for provenancing by neutron activation analyses of ceramics from Bronze Age sites in Greece. JArchaeol Sci 26, 1053–1058.

ITGE. 1992a. *Mapa Geológico de España. Escala 1:50.000, hoja 698/723 (IV), 38‐ 27/38‐ 28. Palma. Isla del Toro y Cap de Cala Figuera*. Madrid: Instituto Tecnológico Geominero de España.

ITGE. 1992b. *Mapa Geológico de España. Escala 1:50.000, hoja 697, 37‐ 27. Andraitx*. Madrid: Instituto Tecnológico Geominero de España.

Maritan, L., 2020. Ceramic abandonment. How to recognise post-depositional transformations. Archaeological and Anthropological Sciences, *12* (8), 1-20.

Mas Florit, C., Cau, M.A. 2008. Una primera aproximació a la tipologia de la ceràmica del taller de Sa Mesquida, in: Cau, M.A. (Ed.), Estudi arqueològic i caracterització arqueomètrica de la ceràmica comuna romana del forn de Sa Mesquida (Calvià, Mallorca). El Tall 16, Palma de Mallorca, pp. 97-106.

Mas Florit, C., Cau, M.A., Orfila, M. 2005. El taller de cerámica de Sa Mesquida (Calviá, Mallorca): una aproximación a la tipología de la cerámica común fina, in: Sánchez-León, M.L., Barceló, M. (Coords.), L'Antiguitat clàssica i la seva pervivència a les Illes Balears. Institut d'Estudis Baleàrics, Palma de Mallorca, pp. 395-408.

Mas Florit, C., Cau Ontiveros, M.A., Pecci, A., Valenzuela, A., in press. A Late Roman Deposit from the Roman Villa of Sa Mesquida (Mallorca, Balearic Islands, Spain), in: Caminneci, V., Parello M.C., Rizzo, M.S. (Eds.) LRCW 6, Late Roman Coarse Wares, Cooking Wares and Amphorae in the Mediterranean: Archaeology and archaeometry. Land and Sea: pottery routes. RLAMP Series, Archaeopress, Oxford.

Mas Florit, C., Vallori, B., Murrieta, P., Rivas, M.J., Cau, M.A., 2015. The Roman villa of Sa Mesquida: a rural settlement on the island of Mallorca (Balearic Islands, Spain), in: Militello, P.M., Öniz, H. (Eds.), SOMA 11, Proceedings of the 15th Symposium on Mediterranean

Archaeology, held at the University of Catania 3-5 March 2011, Vol. I. British Archaeological Reports, International Series, Archaeopress, Oxford, pp. 461-466.

Montana, G., 2000. Ceramic raw materials: how to recognize them and locate the supply basins—mineralogy, petrography. *Archaeological and Anthropological Sciences* 12.8 (2020): 1-19.
Orfila, M., 1989. Cerámicas de la primera mitad del siglo V d.C. procedentes de la cisterna de Sa Mesquida (Santa Ponça, Mallorca), in: Mastino, A. (Ed.), L'Africa romana. Atti del VI Convegno di studio, Sassari, 16-18 dicembre 1988 II. Edizioni Gallizzi, Sassari, pp. 513-533.

Orfila, M., 1993. Construcciones rurales romanas en Mallorca, in: Padró, J. (Ed.), Homenatge a Miquel Tarradell. Estudis Universitaris Catalans XXIX, Curial Edicions Catalanes, Barcelona, pp. 793-806.

Orfila, M., Cardell, J., Cau, M.A., Hernández, Mª.J., Merino, J., Oliver, B., Prohens, J.M., Torres, F., 1996. Nuevas perspectivas en torno a la romanización de la isla de Mallorca: el mundo rural. Mayurqa 23, 9-30.

Orfila, M., Cau, M.A., 1994. Las cerámicas finas procedentes de la cisterna de Sa Mesquida, Calvià (Mallorca), in: III Reunió d'Arqueologia Cristiana Hispànica, Maó, 12-17 de setembre de 1988. Monografies de la Secció Històrico-Arqueològica, Institut d'Estudis Catalans, Barcelona, pp. 257-288.

Papageoriou, I., 2020. Ceramic investigation: how to perform statistical analyses. Archaeological and Anthropological Sciences. 12, 210.

Picon, M., 1973. Introduction à l'étude technique des céramiques sigillées de Lezoux, Centre Pierre Paris.

Picon, M., 1984. Problèmes de détermination de l'origine des céramiques, in: Hackens, T., Schvoerer, M. (Eds.), *Datation - caractérisation des cerámiques anciennes : cours intensif européen, PACT* 10, Bordeaux-Talence, 6-18 abril 1981. Presses du CNRS; Ravello: Centre universitaire européen pour les biens culturels, Paris, pp. 425-433.

Picon, M., 1991. Quelques observations complémentaires sur les altérations de composition des céramiques au cours du temps: cas de quelques alcalins et alcalino-terreux, Rev. d'Archéométrie 15, 117–22.

Privitera, A., Guido, A., Mastandrea, A., Rao, A., Russo, F., 2015. Morphological and mineralogical evolution of microfossils during the heating process: a contribution to the archaeometric study of ceramics. *Rendiconti Lincei Scienze Fisiche e Naturali*, DOI: 10.1007/s12210-015-0443-0.

Quinn, P.S., 2013. Ceramic Petrography. The interpretation of archeological pottery & related artefacts in thin section. Archaeopress, Oxford.

Sabat, F., Muñoz, J.A., Santanach, P., 1988. Transversal and oblique structures at the serres de Llevant thrust belt (Mallorca Island). Geol. Rundsch. 77 (2), 529-538.

Schwedt, A., Mommsen, H., Zacharias, N., Buxeda, J., 2006. Analcime crystallization and compositional profiles —comparing approaches to detect post-depositional alterations in archaeological pottery. Archaeometry 48, 237–51.

Tsantini, E., Buxeda, J., Cau, M.A., Orfila, M., 2004. Caracterización arqueométrica de la cerámica común producida en la villa romana de Sa Mesquida (Mallorca). Pyrenae 35 (1), 157-186.

Vallespir, A., Prohens, J.M., Orfila, M., Merino, J., 1985-1987. Yacimientos arqueológicos de Santa Ponça. Mayurqa 21, 1-30.

Weigand, P.C., Harbottle, G., Sayre, E.V., 1977. Turquoise sources and source analysis: Mesoamerica and the Southwestern U.S.A., in: Earle, T.K., Ericson, J.E. (Eds.), *Exchange systems in prehistory*. Studies in Archeology, Academic Press Inc, New York and London, pp. 15-34.

Whitbread, I.K., 1989. A proposal for the systematic description of thin sections towards the study of ancient ceramic technology, in: Maniatis, Y. (Ed.), Archaeometry: proceedings of the 25th international symposium. Elsevier, Amsterdam, pp. 127-138.

Whitbread, I.K., 1995. Appendix 3. The collection, processing and interpretation of petrographic data, in: Whitbread, I.K., Greek transport amphorae: a petrological and archaeological study. Fitch Laboratory Occasional Papers. 4, British School at Athens, Athens, pp. 365-396.

Figure captions

Figure 1. a) Location of Sa Mesquida in Mallorca, Balearic Islands, western Mediterranean. b) Preserved structures of the Roman site of Sa Mesquida (Santa Ponça, Mallorca)

Figure 2. A simplified geological map of the study area, showing the location of Sa Mesquida (based on ITGE 1992a, 1992b)

Figure 3. a) Line-graph of the variability each one of the chemical elements introduces in the data set (τ_i); b) Cluster tree of the 77 new samples from Sa Mesquida (labeled MC and MCFN), performed using the centroid agglomerative method and squared Euclidean distance, based on the alr transformed subcomposition Fe_2O_3, Al_2O_3, MnO, TiO_2, MgO, CaO, SiO_2, K_2O, Na_2O, Ba, Th, Nb, Zr, Y, Sr, Ce, V, Zn, Rb, Cu, Ni, using Ga as divisor.

Figure 4. An example of the XRD pattern of an individual (MCFN060) with analcime. Abbreviations for minerals: qtz, quartz; kfs, K-feldspar; pg, plagioclase; hem, hematite; px, pyroxene; anal, analcime

Figure 5. Principal component analysis on the 77 new samples from Sa Mesquida, based on the same alr transformed subcomposition Fe_2O_3 (as total Fe), TiO_2, MgO, CaO, SiO_2, Ba, Th, Nb, Zr, Y, Sr, Ce, Ga, V, Zn, Ni and Cr, using Al_2O_3 as divisor. Bi-plot of the 1st and 2nd principal components.

Figure 6. a) Line-graph of the variability each one of the chemical elements introduces in the data set (τ_i); b) Cluster tree of the samples from Sa Mesquida (including the Early Imperial kiln's RG), performed using the centroid agglomerative method and squared Euclidean distance, based on the alr transformed subcomposition: Fe_2O_3 (as total Fe), TiO_2, MgO, CaO, SiO_2, Ba, Th, Nb, Zr, Y, Sr, Ce, Ga, V, Zn, Ni and Cr, using Al_2O_3 as divisor.

Figure 7. Principal component analysis of the samples from Sa Mesquida, based on the same alr transformed subcomposition as the cluster analysis in Figure 6. Bi-plot of the 1st and 3rd principal components.

Figure 8. Photomicrographs of ceramic thin sections taken in crossed polarized light. Early Roman Imperial kiln, samples MCF012 (a) and MCF017 (b); Late Republican/Augustan context, sample MCFN064 (c); 2nd-3rd century AD context, sample MCFN060 (d); 4th-5th century AD context, sample MCFN056 (e); 5th-7th century AD context, samples MC1001 (f), MC1008 (g); MC1028 (h); MC1009 (i).

Figure 9. Some of the types represented in Groups G1.

Figure 10. Some of the types represented in Group G2.

Figure 11. Some of the types represented in Groups G3 and G4.

Table captions

Table 1. List of the analyzed samples, with their main archaeological information, and the outcome of the analytical study.

Table 2. Raw chemical composition of the individuals analyzed by WD-XRF (with major and minor elements expressed in % of the oxide; trace elements expressed in part per million (ppm); LOI= loss on ignition).

Table 3. Mean chemical composition, standard deviation, maximum, and minimum values for each one of the elements determined for the four groups (G1 to G4), also adding the Reference Group for the kiln of Sa Mesquida (n=54). In parentheses (indicated with *) the mean and standard deviation values calculated after excluding the individuals with analcime precipitation.

Figure 1 Click here to access/download;Figure;FIGURE1_FINAL_modificada.jpg

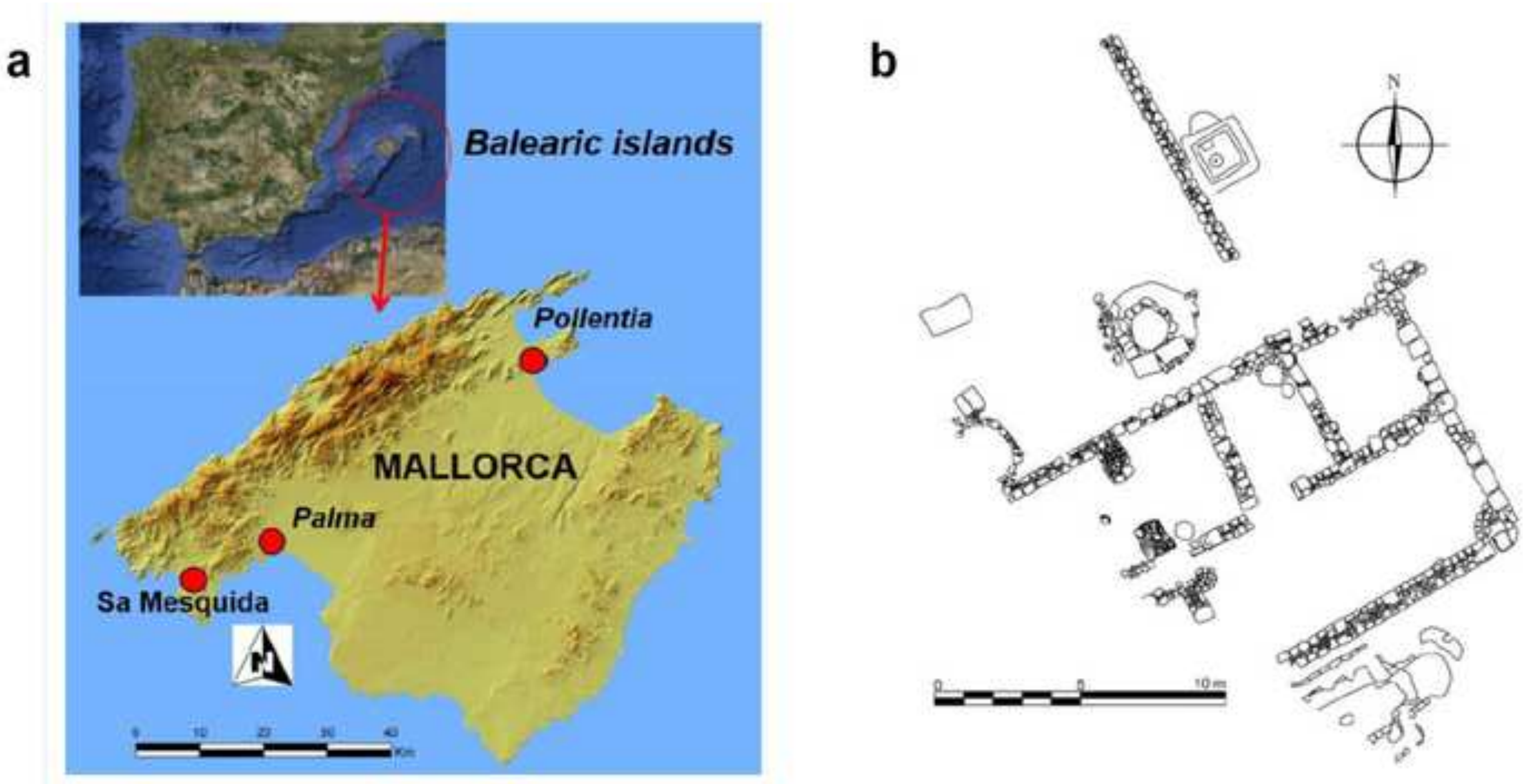


Figure 2

Click here to
access/download;Figure;FIGURE2_FINAl_modificada.jpg

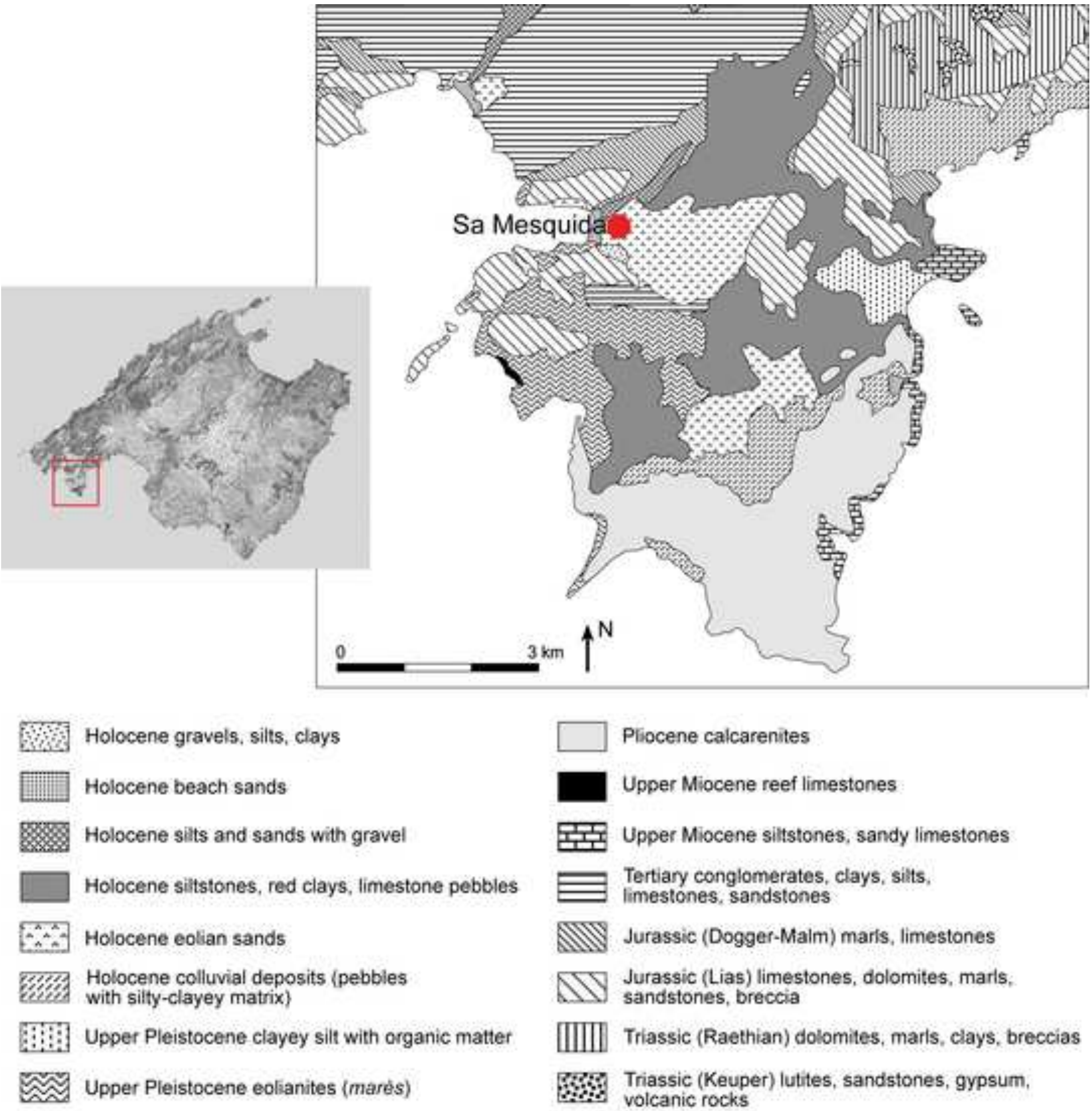


Figure 3

Click here to access/download;Figure;FIGURE3_FINAL_modificada.jpg

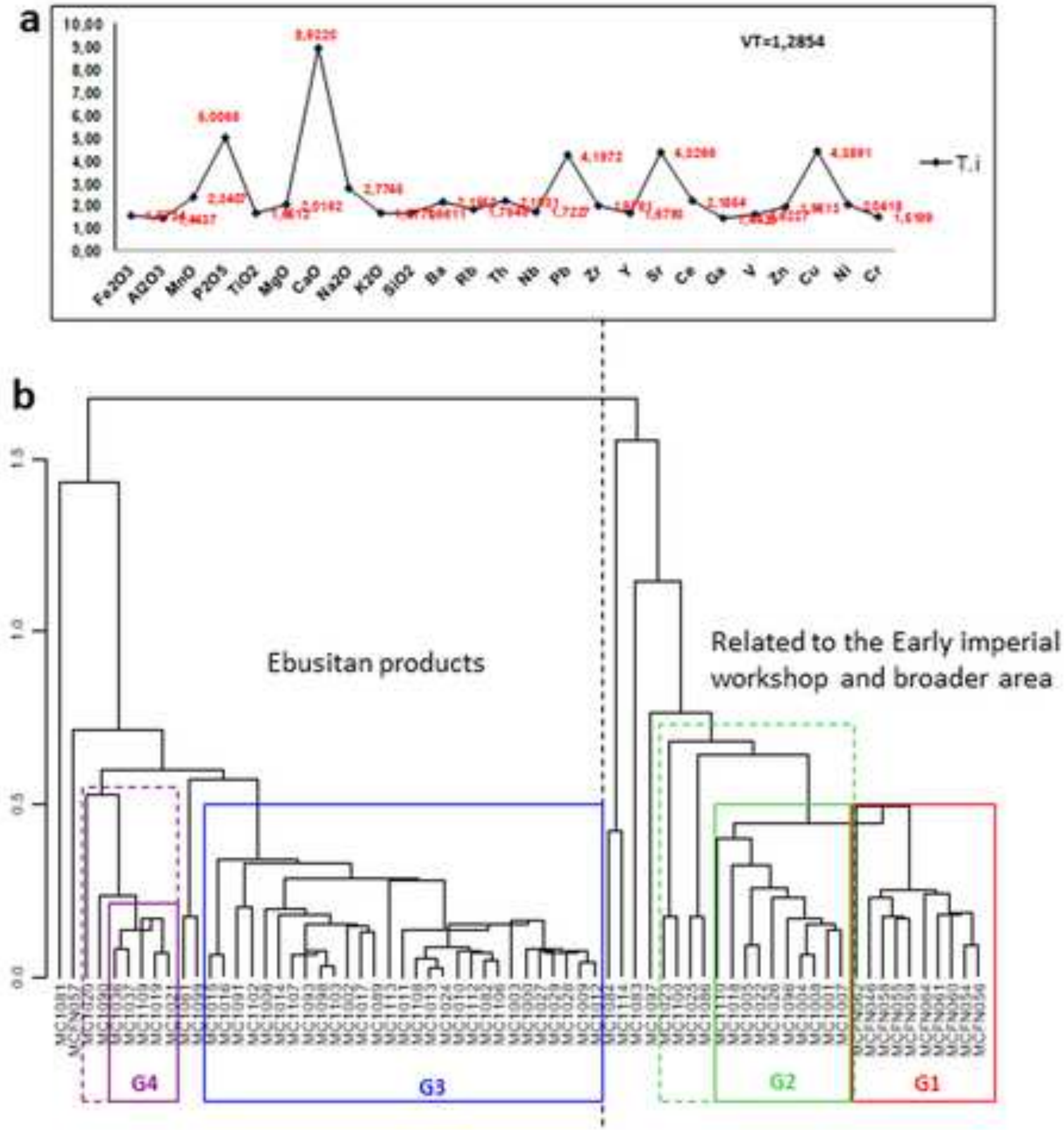


Figure 4

Click here to access/download;Figure;FIGURE4_FINAL_modificada.jpg

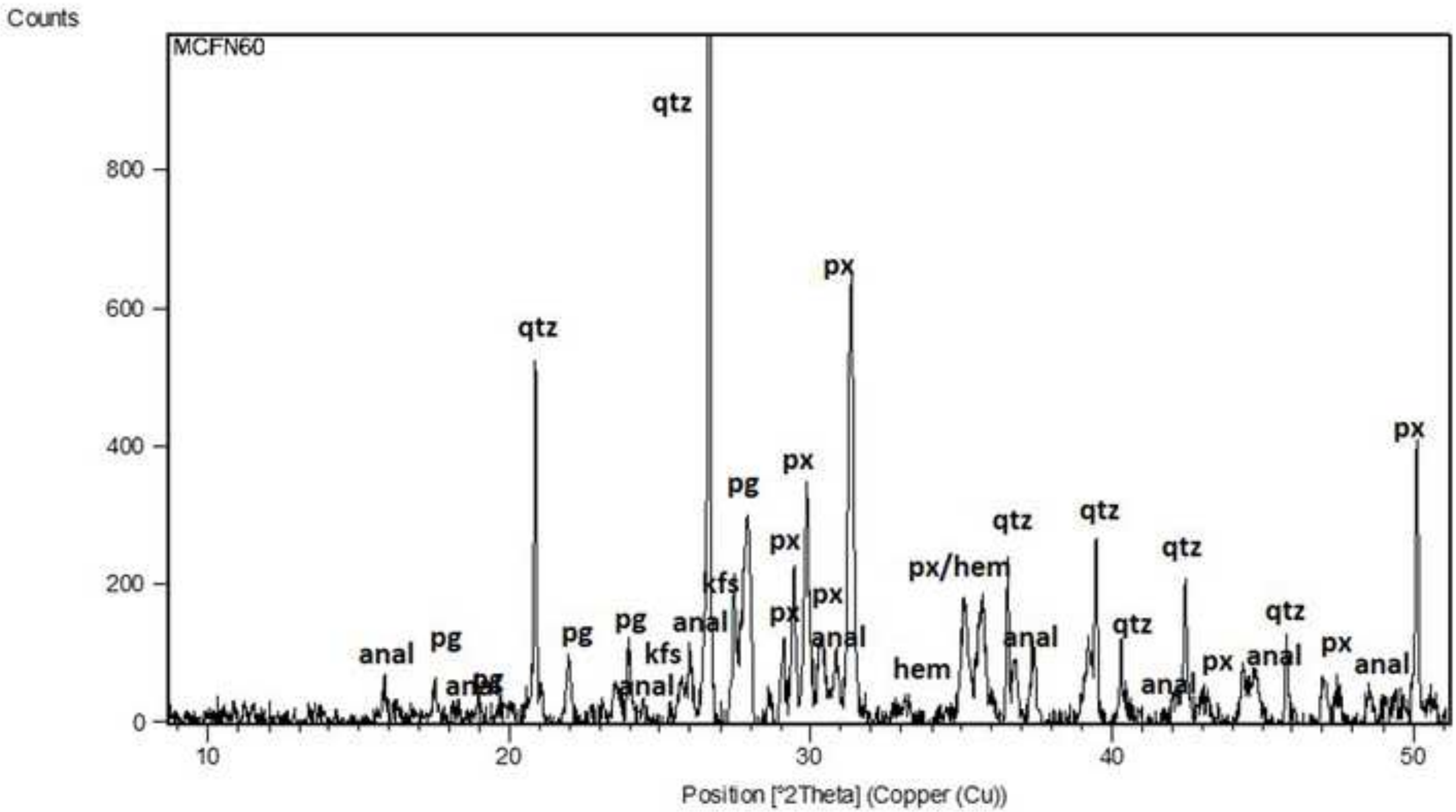


Figure 5

Click here to access/download;Figure;FIGURE5_FINAL.tif

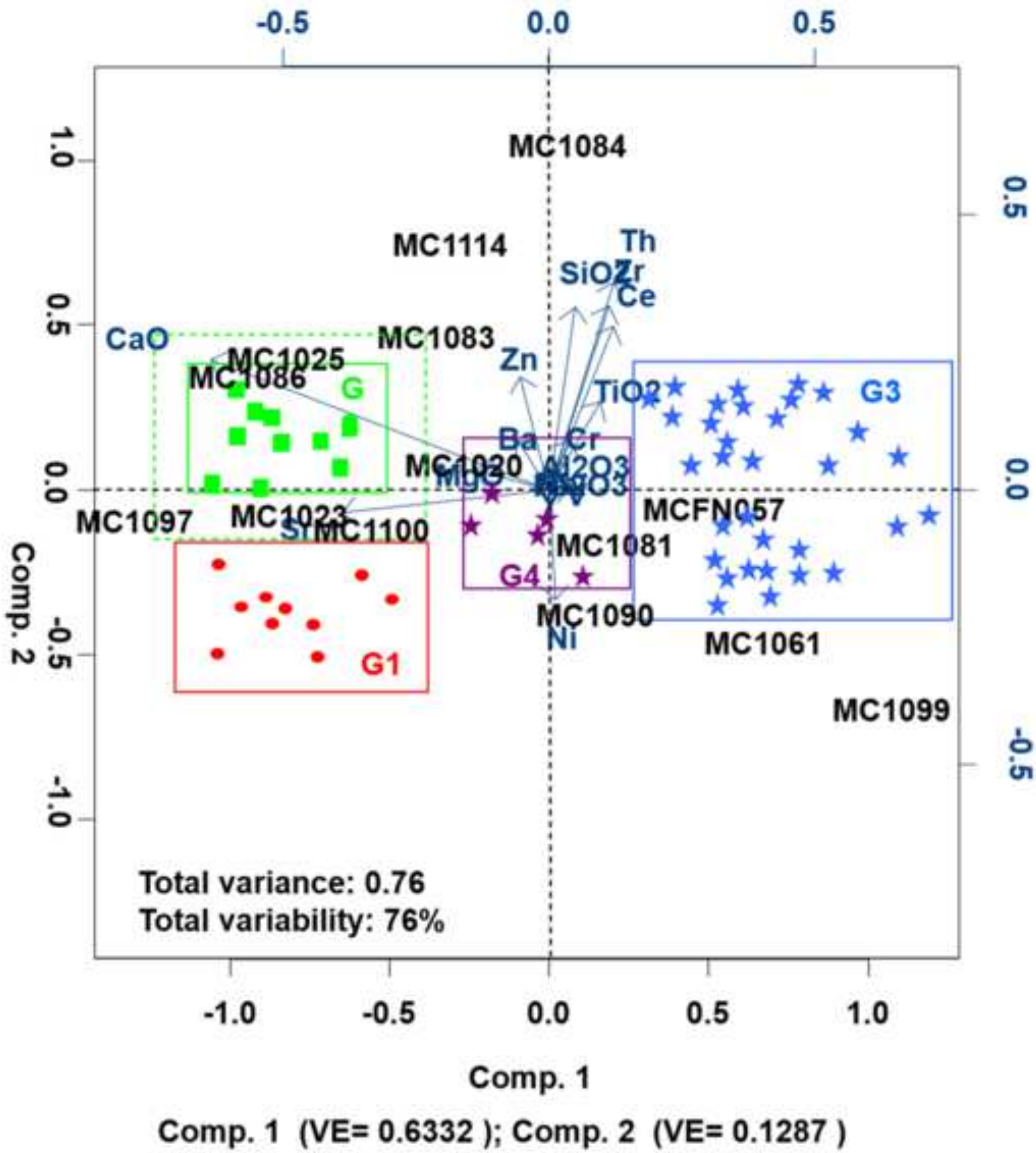


Figure 6

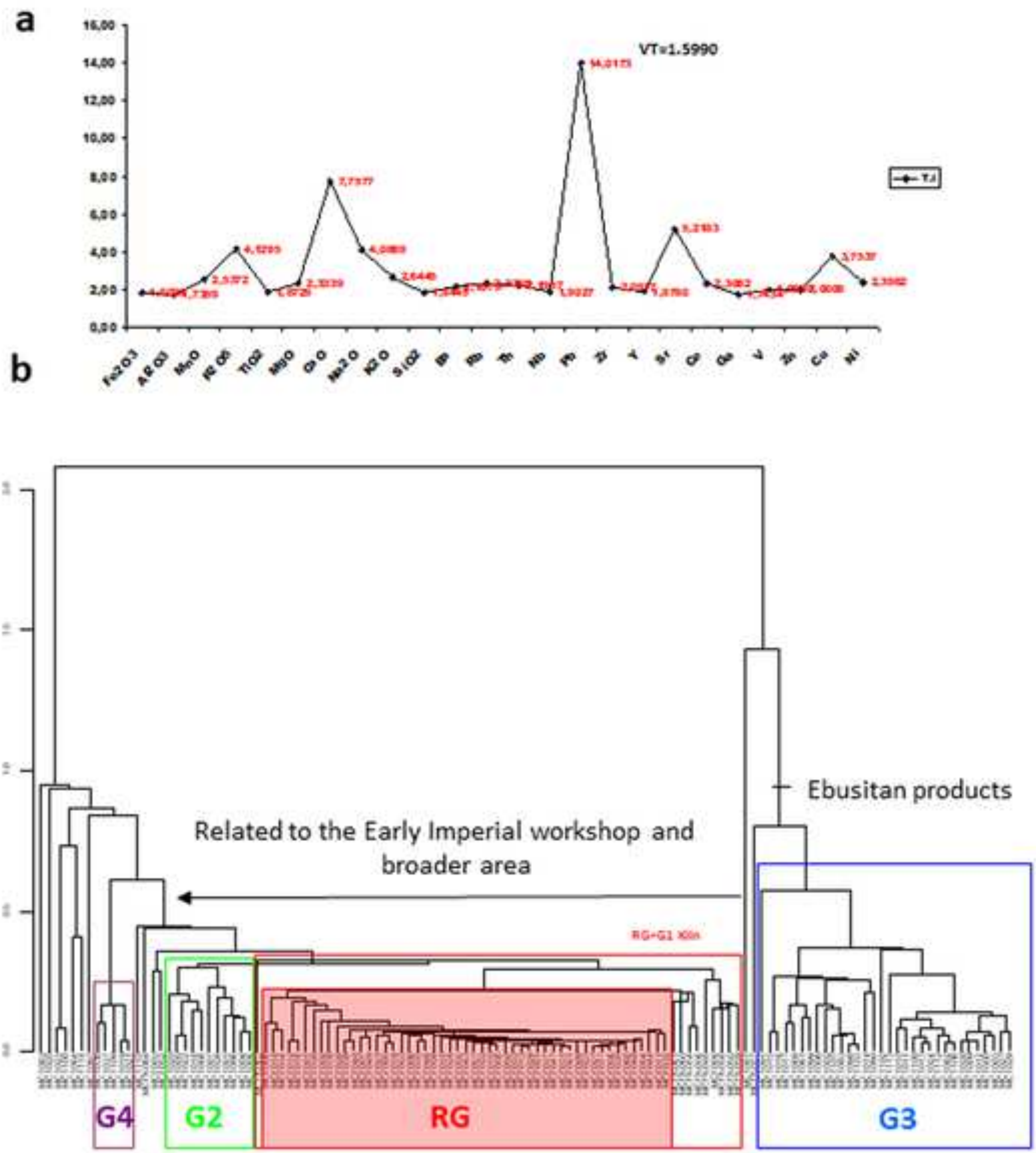
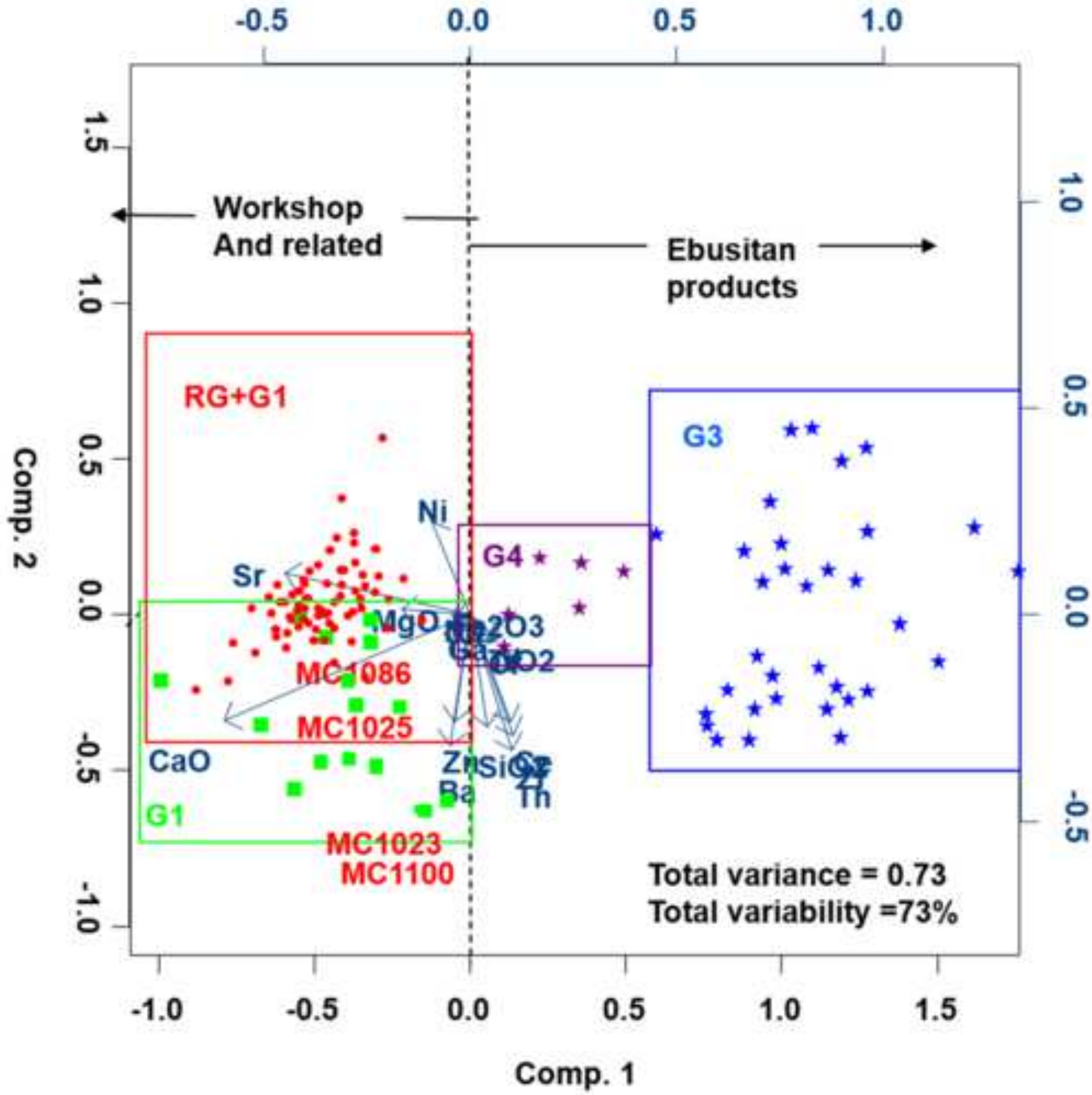

a
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
VT=1.5990
b
Ebusitan products
Related to the Early Imperial workshop and broader area
G4
G2
RG
G3

Figure 7

Click here to access/download;Figure;FIGURE7_FINAL.tif



Comp. 1 (VE= 0.7287); Comp. 2 (VE= 0.0825)

Figure 8

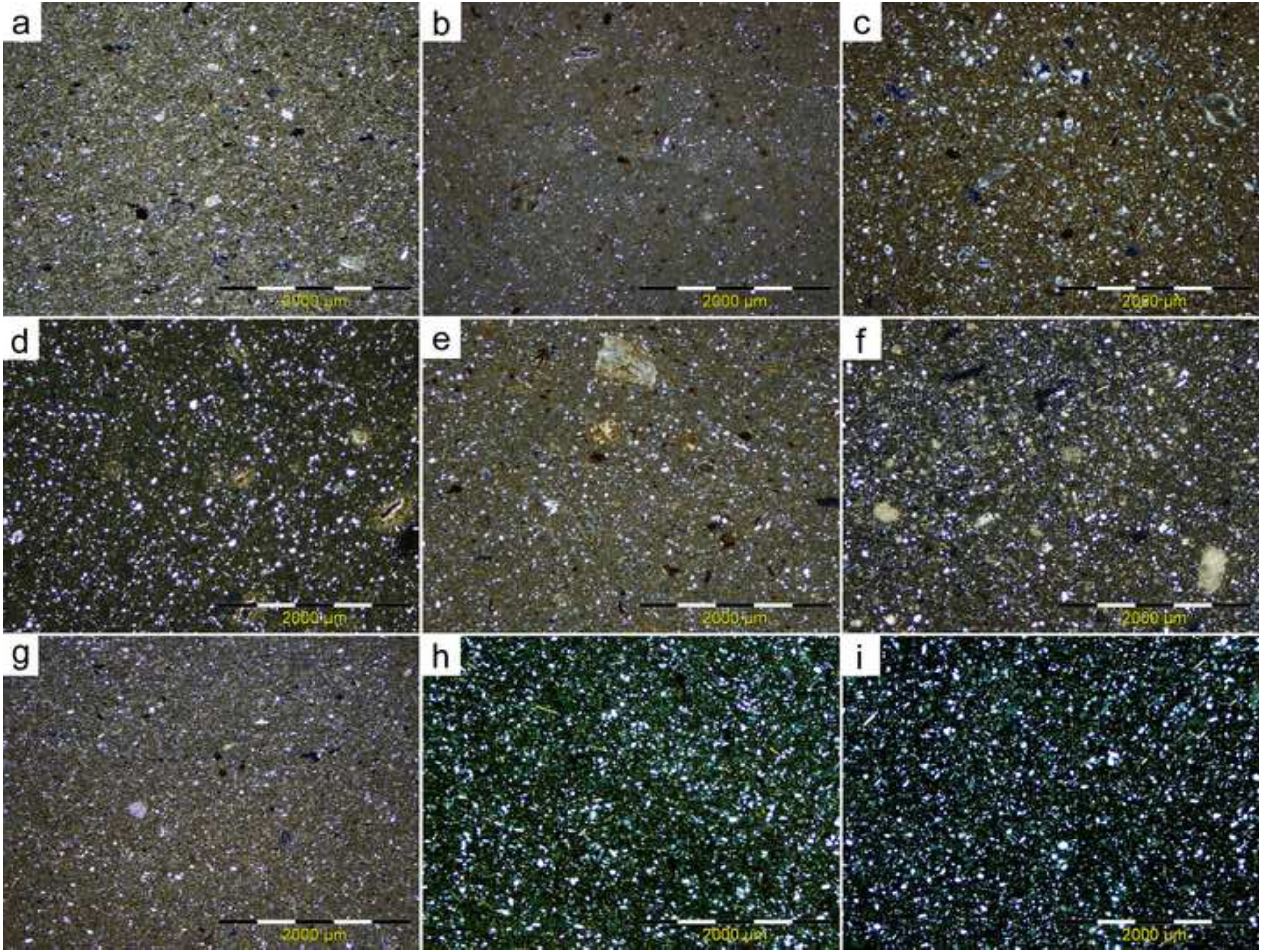


Figure 9

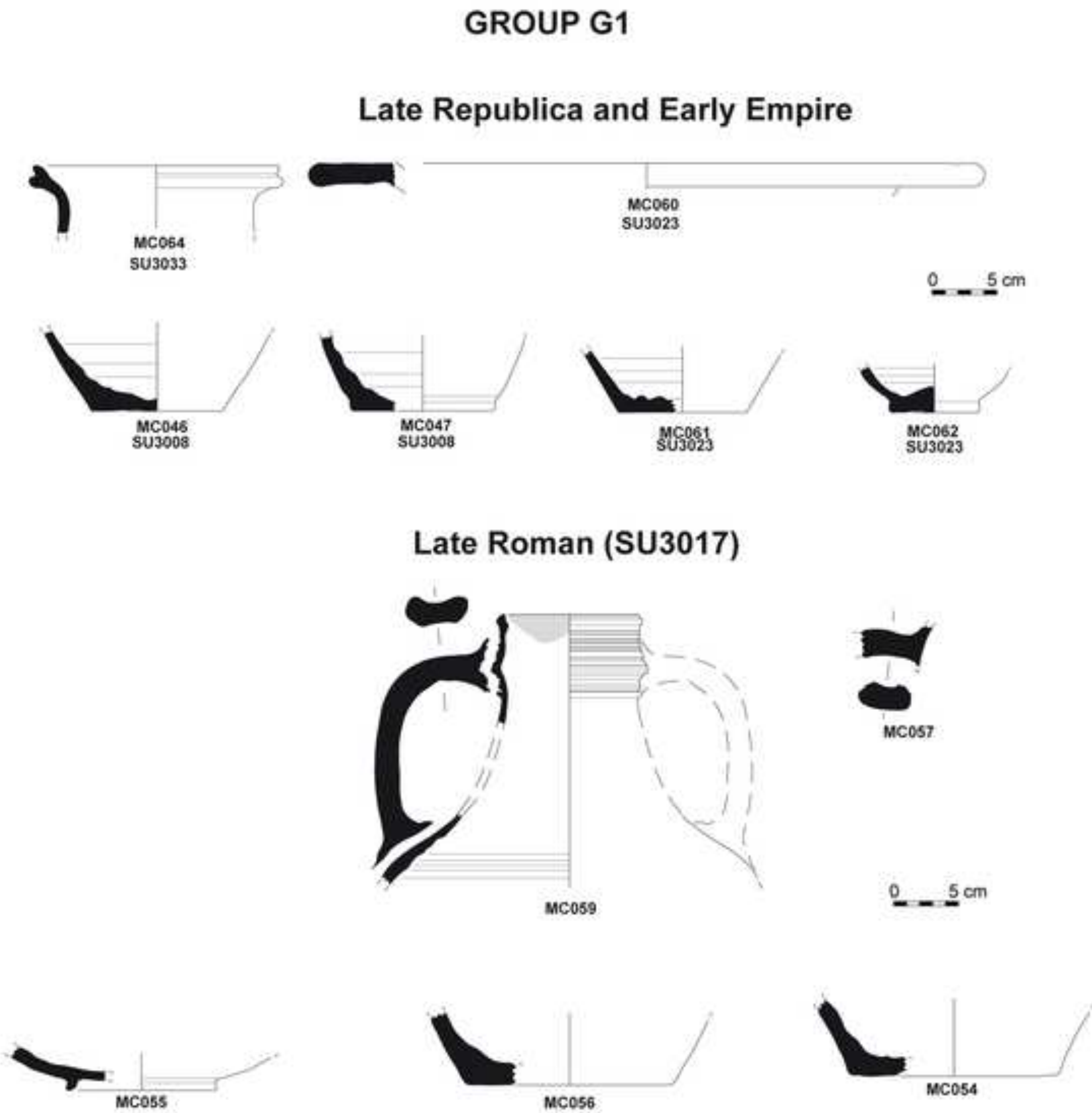

GROUP G1
Late Republica and Early Empire
MC064
SU3033
MC060
SU3023
0 5 cm
MC046
SU3008
MC047
SU3008
MC061
SU3023
MC062
SU3023
Late Roman (SU3017)
MC057
MC059
0 5 cm
MC055
MC056
MC054

Figure 10

Click here to access/download;Figure;FIGURE10_FINAL_modificado.jpg

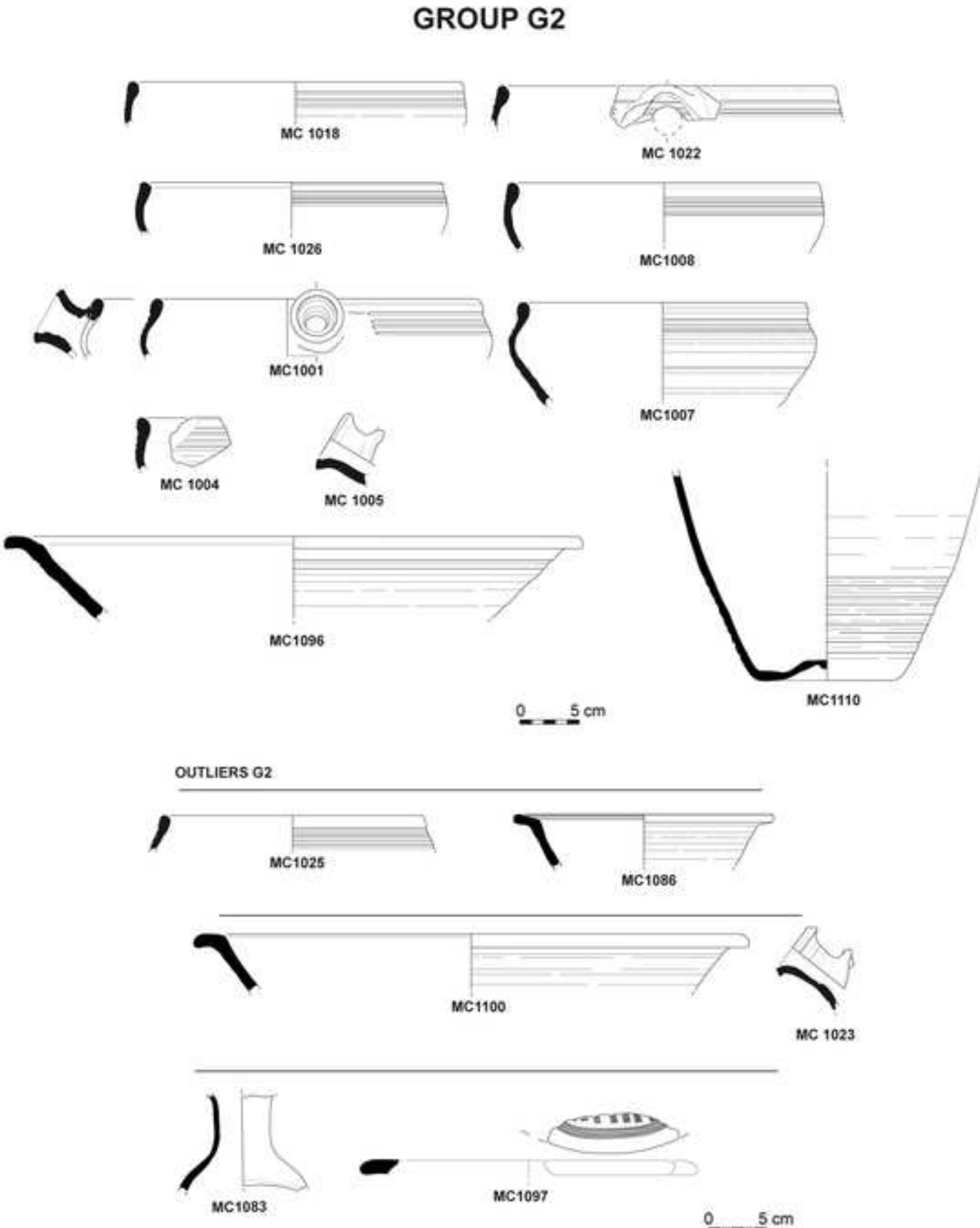


Figure 11 Click here to access/download;Figure;FIGURE11_FINAL_modificado.jpg

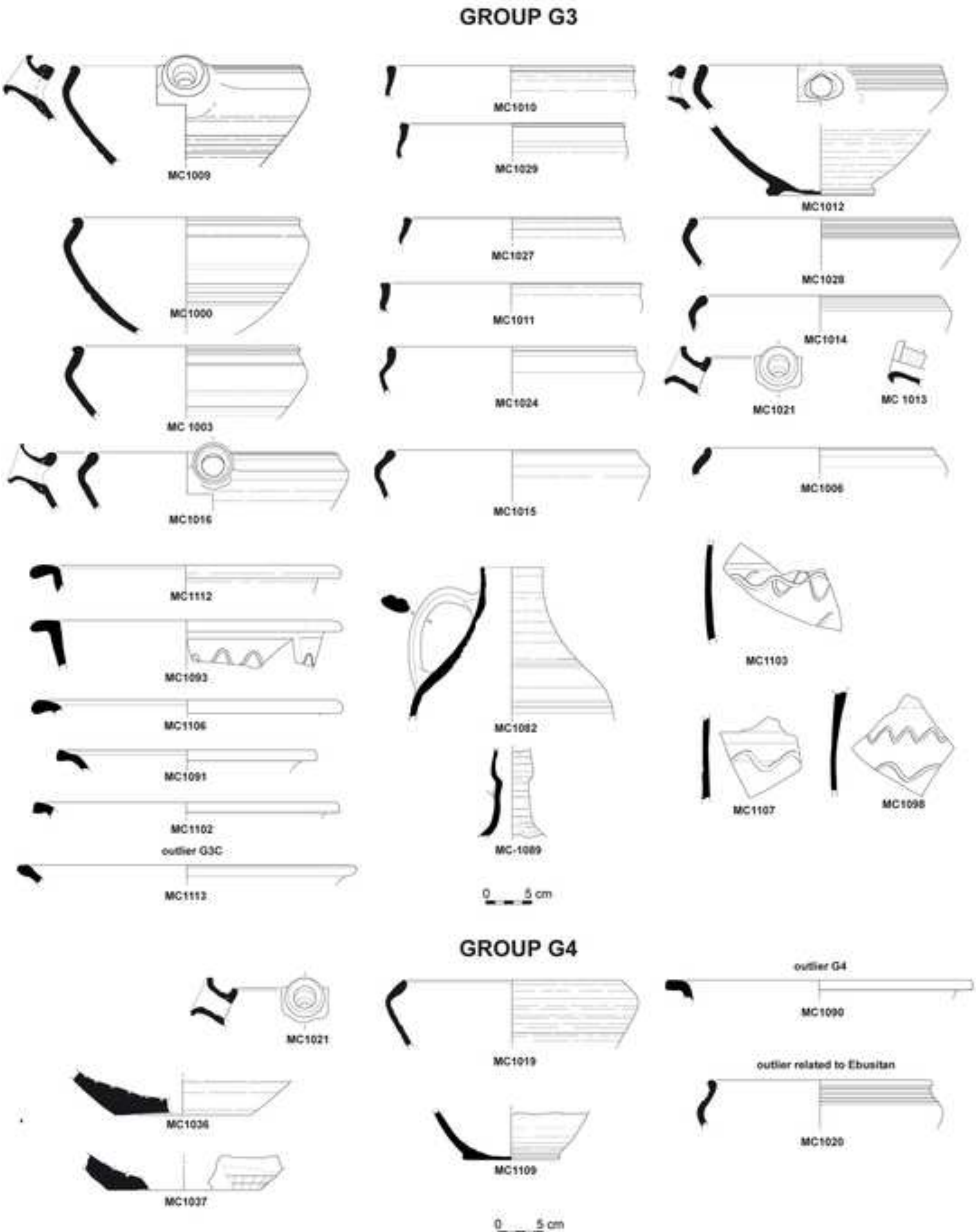


Table 1 Click here to access/download;Table;Table 1.xlsx

Samples	WD-XRF	OM	Sector / context
MC1000	X	X	Cistern: rubbish dump
MC1001	X	X	Cistern: rubbish dump
MC1002	X	-	Cistern: rubbish dump
MC1003	X	X	Cistern: rubbish dump
MC1004	X	-	Cistern: rubbish dump
MC1005	X	X	Cistern: rubbish dump
MC1006	X	X	Cistern: rubbish dump
MC1007	X	X	Cistern: rubbish dump
MC1008	X	X	Cistern: rubbish dump
MC1009	X	X	Cistern: rubbish dump
MC1010	X	-	Cistern: rubbish dump
MC1011	X	-	Cistern: rubbish dump
MC1012	X	X	Cistern: rubbish dump
MC1013	X	X	Cistern: rubbish dump
MC1014	X	X	Cistern: rubbish dump
MC1015	X	X	Cistern: rubbish dump
MC1016	X	X	Cistern: rubbish dump
MC1017	X	-	Cistern: rubbish dump
MC1018	X	-	Cistern: rubbish dump
MC1019	X	X	Cistern: rubbish dump
MC1020	X	X	Cistern: rubbish dump
MC1021	X	X	Cistern: rubbish dump
MC1022	X	X	Cistern: rubbish dump
MC1023	X	X	Cistern: rubbish dump
MC1024	X	X	Cistern: rubbish dump
MC1025	X	-	Cistern: rubbish dump
MC1026	X	-	Cistern: rubbish dump
MC1027	X	-	Cistern: rubbish dump
MC1028	X	X	Cistern: rubbish dump
MC1029	X	X	Cistern: rubbish dump
MC1033	X	X	Cistern: rubbish dump
MC1036	X	X	Cistern: rubbish dump
MC1037	X	X	Cistern: rubbish dump
MC1047	X	X	Cistern: rubbish dump
MC1061	X	-	Cistern: rubbish dump
MC1081	X	-	Cistern: rubbish dump
MC1082	X	-	Cistern: rubbish dump
MC1083	X	-	Cistern: rubbish dump
MC1084	X	-	Cistern: rubbish dump
MC1086	X	-	Cistern: rubbish dump
MC1089	X	-	Cistern: rubbish dump
MC1090	X	-	Cistern: rubbish dump
MC1091	X	-	Cistern: rubbish dump
MC1093	X	-	Cistern: rubbish dump
MC1096	X	-	Cistern: rubbish dump
MC1097	X	-	Cistern: rubbish dump
MC1098	X	-	Cistern: rubbish dump
MC1099	X	-	Cistern: rubbish dump
MC1100	X	-	Cistern: rubbish dump
MC1102	X	-	Cistern: rubbish dump
MC1103	X	-	Cistern: rubbish dump
MC1106	X	-	Cistern: rubbish dump
MC1107	X	X	Cistern: rubbish dump
MC1108	X	-	Cistern: rubbish dump
MC1109	X	-	Cistern: rubbish dump
MC1110	X	-	Cistern: rubbish dump
MC1112	X	-	Cistern: rubbish dump
MC1113	X	-	Cistern: rubbish dump

MC1114	X	-	Cistern: rubbish dump
MCFN046	X	-	Roman villa
MCFN054	X	X	Rubbish dump infilling the kiln
MCFN055	X	X	Rubbish dump infilling the kiln
MCFN056	X	X	Rubbish dump infilling the kiln
MCFN057	X	X	Rubbish dump infilling the kiln
MCFN058	X	X	Rubbish dump infilling the kiln
MCFN059	X	X	Rubbish dump infilling the kiln
MCFN060	X	X	Abandonment of the kiln
MCFN061	X	X	Abandonment of the kiln
MCFN062	X	X	Abandonment of the kiln
MCFN064	X	X	Roman villa: earliest phase (construction)
MCFN082	-	X	Roman villa: earliest phase (construction)
MCFN083	-	X	Rubbish dump infilling the kiln
MCFN084	-	X	Roman villa: earliest phase (construction)
MCFN087	-	X	Rubbish dump infilling the kiln
MCFN088	-	X	Abandonment of the kiln
MCFN089	-	X	Roman villa
MCF001	X	X	Kiln
MCF002	X	-	Kiln
MCF003	X	-	Kiln
MCF004	X	-	Kiln
MCF005	X	-	Kiln
MCF006	X	-	Kiln
MCF007	X	X	Kiln
MCF008	X	X	Kiln
MCF009	X	-	Kiln
MCF010	X	-	Kiln
MCF011	X	-	Kiln
MCF012	X	X	Kiln
MCF013	X	-	Kiln
MCF014	X	-	Kiln
MCF015	X	-	Kiln
MCF016	X	-	Kiln
MCF017	X	X	Kiln
MCF018	X	X	Kiln
MCF019	X	-	Kiln
MCF021	X	-	Kiln
MCF022	X	X	Kiln
MCF023	X	-	Kiln
MCF024	X	-	Kiln
MCF027	X	-	Kiln
MCF028	X	-	Kiln
MCF029	X	-	Kiln
MCF030	X	-	Kiln
MCF031	X	-	Kiln
MCF032	X	-	Kiln
MCF033	X	-	Kiln
MCF034	X	-	Kiln
MCF035	X	-	Kiln
MCF037	X	-	Kiln
MCF038	X	-	Kiln
MCF039	X	-	Kiln
MCF040	X	-	Kiln
MCF041	X	-	Kiln
MCF043	X	-	Kiln
MCF044	X	-	Kiln
MCF046	X	-	Kiln
MCF047	X	-	Kiln

MCF048	X	-	Kiln
MCF049	X	-	Kiln
MCF050	X	-	Kiln
MCF051	X	-	Kiln
MCF052	X	-	Kiln
MCF053	X	-	Kiln
MCF054	X	-	Kiln
MCF055	X	-	Kiln
MCF056	X	-	Kiln
MCF057	X	-	Kiln
MCF058	X	-	Kiln
MCF059	X	-	Kiln
MCF060	X	-	Kiln

Chronology of stratigraphic unit	Initial archaeological hypothesis	Chemical group
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G4
5th-7th century AD	Ebusitan	G4?
5th-7th century AD	Ebusitan	G4
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G2?
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G2?
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	outlier
5th-7th century AD	Ebusitan	G4
5th-7th century AD	Ebusitan	G4
5th-7th century AD	Ebusitan	outlier
5th-7th century AD	?	outlier with 1099
5th-7th century AD	Ebusitan	outlier
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	outlier
5th-7th century AD	Ebusitan	outlier with MC1114
5th-7th century AD	Ebusitan	G2?
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G4?
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	outlier/loner
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	outlier with MC1061
5th-7th century AD	Ebusitan	G2?
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G4
5th-7th century AD	Ebusitan	G2
5th-7th century AD	Ebusitan	G3
5th-7th century AD	Ebusitan	G3

5th-7th century AD	Ebusitan	outlier with MC1084
Early Roman Imperial	local	G1
Late 4th to early 5th century AD	local	G1
Late 4th to early 5th century AD	local	G1
Late 4th to early 5th century AD	local	G1
Late 4th to early 5th century AD	local	outlier/loner
Late 4th to early 5th century AD	local	G1
Late 4th to early 5th century AD	local	G1
Late 2nd to early 3rd century AD	local	G1
Late 2nd to early 3rd century AD	local	G1
Late 2nd to early 3rd century AD	local	G1
Late Republican or Augustan	local	G1
Late Republican or Augustan	Ebusitan	no WDXRF
Late 4th to early 5th century AD	local	no WDXRF
Late Republican or Augustan	local	no WDXRF
Late 4th to early 5th century AD	Ebusitan	no WDXRF
Late 2nd to early 3rd century AD	local	no WDXRF
Early Roman Imperial	local	no WDXRF
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group

Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group
Early Roman Imperial	local	Local Reference Group

Petrography	Observations
Ebusitan	
local	
no OM	
Ebusitan	
no OM	
local	
Ebusitan	
local	
local	
Ebusitan	
no OM	
no OM	
Ebusitan	
Ebusitan	
Ebusitan	
Ebusitan	
Ebusitan	
no OM	
no OM	
Ebusitan	
Ebusitan	
Ebusitan	
Ebusitan	
Ebusitan	
Ebusitan	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
Ebusitan	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
no OM	
Ebusitan	
no OM	
no OM	
no OM	
no OM	
no OM	

no OM
no OM
local
local
local
local
local
local
local
local
local
Ebusitan
local
local but coarser
Ebusitan
local
local
local
no OM
no OM
no OM
no OM
no OM
local
local
no OM
no OM
no OM
local
no OM
no OM
no OM
no OM
local
local
no OM
no OM
local
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM

no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM
no OM

Table 2

CODE	Fe_2O_3	Al_2O_3	MnO	P_2O_5	TiO_2	MgO	CaO	Na_2O	K_2O	SiO_2	Ba	Rb
MCF001	3.95	14.61	0.02	0.21	0.79	1.46	19.57	0.69	3.07	45.7	0.0435	0.0133
MCF002	4.09	14.95	0.02	0.24	0.68	1.69	21.61	0.59	2.73	46.43	0.0349	0.0115
MCF003	4.29	15.5	0.02	0.2	0.69	1.66	20.03	1.14	2.09	47.47	0.0339	0.0081
MCF004	4.33	14.21	0.03	0.23	0.57	1.34	22.86	1.1	2.41	43.43	0.0479	0.0108
MCF005	4.31	16.31	0.02	0.21	0.7	1.75	18.54	0.6	3.3	48.68	0.0398	0.0161
MCF006	4.07	14.76	0.02	0.18	0.64	1.47	19.74	0.53	3.11	47.17	0.0364	0.0140
MCF007	4.25	14.83	0.02	0.22	0.62	1.53	20.33	0.56	2.89	47.21	0.0382	0.0135
MCF008	4.8	15.97	0.02	0.22	0.7	1.87	18.79	2.07	1.04	46.24	0.0287	0.0062
MCF009	4.25	15.3	0.02	0.26	0.66	1.62	19.33	0.62	2.99	47.35	0.0343	0.0141
MCF010	4.17	15.3	0.02	0.21	0.65	1.69	20.52	1.38	1.8	47.31	0.0337	0.0084
MCF011	4.21	14.88	0.02	0.21	0.61	1.82	19.94	0.68	2.76	47.53	0.0402	0.0126
MCF012	4.14	14.4	0.02	0.23	0.6	1.48	18.52	0.59	2.91	45.61	0.0475	0.0140
MCF013	4.14	15.38	0.02	0.21	0.67	1.7	20.34	0.72	2.9	47.71	0.0368	0.0126
MCF014	4.32	15.27	0.02	0.19	0.66	1.68	19.74	1.98	1.08	46.23	0.0273	0.0062
MCF015	4.29	14.62	0.02	0.19	0.63	1.61	20.83	0.58	2.84	47.14	0.0368	0.0128
MCF016	3.98	14.57	0.02	0.18	0.57	1.54	20.92	0.58	2.82	46.14	0.0369	0.0140
MCF017	4.09	15	0.02	0.16	0.6	1.66	21.22	0.62	2.88	47.48	0.0354	0.0139
MCF018	4.04	14.18	0.02	0.2	0.58	1.49	19.94	0.55	2.93	45.09	0.0433	0.0141
MCF019	4.23	15.96	0.02	0.22	0.68	1.69	18.78	0.63	3.4	47.98	0.0383	0.0178
MCF021	4.65	16.4	0.03	0.19	0.71	1.73	17.7	1.24	2.26	51.15	0.0385	0.0099
MCF022	4.26	15.12	0.02	0.21	0.68	1.7	21.13	1.16	2.15	47.53	0.0323	0.0090
MCF023	4.19	15.34	0.02	0.19	0.64	1.74	20.58	0.64	2.88	46.85	0.0330	0.0128
MCF024	4.21	15.2	0.02	0.2	0.66	1.73	18.92	0.58	2.88	48.54	0.0396	0.0138
MCF027	4.02	15.07	0.02	0.19	0.66	1.73	20.4	0.55	3.01	47.18	0.0346	0.0149
MCF028	4.06	15.37	0.02	0.21	0.62	1.73	20.54	0.64	2.84	46.95	0.0370	0.0133
MCF029	4.05	15.08	0.02	0.22	0.65	1.67	20.33	0.64	2.81	46.3	0.0376	0.0137
MCF030	4.19	14.44	0.03	0.19	0.6	1.66	21.72	0.6	2.68	46.14	0.0329	0.0125
MCF031	4.44	15.1	0.03	0.26	0.63	1.71	20.39	0.81	2.86	46.61	0.0400	0.0127
MCF032	4.21	14.62	0.02	0.21	0.6	2.21	19.17	0.6	2.82	48	0.0376	0.0130
MCF033	4.11	15.07	0.02	0.21	0.66	1.71	21.47	0.65	2.7	46.61	0.0363	0.0123
MCF034	4.36	16.01	0.02	0.2	0.66	1.73	19.1	1.92	1.15	46.81	0.0308	0.0065
MCF035	3.91	14.44	0.02	0.19	0.64	1.46	19.53	0.53	3.01	46.48	0.0390	0.0141
MCF037	4.29	15.73	0.02	0.23	0.66	1.76	19.95	0.98	2.84	49.25	0.0390	0.0119
MCF038	4.23	14.92	0.02	0.2	0.69	1.66	20.54	1.69	1.33	46.81	0.0268	0.0076
MCF039	4.36	15.41	0.02	0.23	0.62	1.72	19.83	0.83	2.81	48.88	0.0380	0.0124
MCF040	4.22	15.17	0.02	0.22	0.63	1.74	20.33	0.76	2.81	47.76	0.0411	0.0121
MCF041	4.26	15.12	0.02	0.22	0.64	1.7	20.22	0.75	2.78	48.72	0.0402	0.0123
MCF043	4.14	14.22	0.02	0.22	0.65	1.57	20.6	0.69	2.8	45.38	0.0337	0.0132
MCF044	4.31	15.69	0.02	0.23	0.66	1.93	18.21	0.53	2.98	47.47	0.0385	0.0141
MCF046	4.1	14.61	0.02	0.23	0.62	1.49	20.49	0.69	2.89	47.3	0.0445	0.0136
MCF047	4.3	15	0.02	0.21	0.64	1.66	19.88	0.87	2.9	47.73	0.0384	0.013
MCF048	4.13	15.07	0.02	0.21	0.64	1.7	20.2	0.68	2.85	47.39	0.0349	0.0126
MCF049	3.99	14.07	0.02	0.21	0.58	1.61	19.44	0.59	3.01	45.6	0.0362	0.0135
MCF050	4.16	14.61	0.02	0.23	0.66	1.66	20.67	0.61	2.88	46.79	0.035	0.013
MCF051	4.11	14.91	0.02	0.24	0.66	1.61	19.92	0.69	2.86	47.99	0.0356	0.0129
MCF052	4.61	16.69	0.02	0.21	0.69	1.76	18.57	1.83	1.35	49.26	0.0272	0.0077
MCF053	4.3	15.56	0.02	0.22	0.69	1.65	19.62	0.7	2.91	48.27	0.0395	0.0132
MCF054	4.26	15.28	0.02	0.23	0.65	1.7	20.17	0.74	2.78	47.82	0.0341	0.0130
MCF055	4.21	14.68	0.02	0.18	0.65	1.89	19.88	0.83	2.8	47.61	0.0397	0.0128
MCF056	4.06	14.79	0.02	0.2	0.63	1.64	20.47	0.65	2.86	47.03	0.0366	0.0135
MCF057	4.15	15.01	0.02	0.19	0.59	1.68	21.12	0.59	2.86	46.7	0.0336	0.0137
MCF058	4.07	14.78	0.02	0.19	0.65	1.64	20.71	0.63	2.87	46.61	0.0345	0.0134
MCF059	4.18	15.03	0.02	0.19	0.66	1.67	20.92	1.45	1.6	46.95	0.0295	0.0082
MCF060	4.11	14.49	0.02	0.2	0.63	1.63	21.6	0.67	2.78	46.72	0.0325	0.0123
MCFN046	4.145	13.265	0.0229	0.22	0.57	1.43	27.62	0.49	2.425	39.645	0.0500	0.0097
MCFN054	4.5	14.625	0.0202	0.20	0.60	1.71	21.305	0.62	2.76	46.315	0.0423	0.0124
MCFN055	4.585	14.77	0.0268	0.22	0.56	1.455	25.49	0.415	2.81	42.575	0.0413	0.0098
MCFN056	4.05	13.875	0.0159	0.16	0.57	1.905	19.175	0.495	2.815	44.945	0.0386	0.0124
MCFN057	4.035	14.75	0.0198	0.20	0.77	1.025	10.37	0.73	2.925	61.745	0.0362	0.0124
MCFN058	4.43	14.705	0.0199	0.27	0.56	1.58	25.84	0.895	2.1	42.795	0.0570	0.0078
MCFN059	4.62	14.3	0.0168	0.14	0.56	1.425	22.59	0.43	2.99	42.8	0.0494	0.0128
MCFN060	5.12	16.81	0.0201	0.16	0.69	1.76	17.325	1.205	2.535	51.96	0.0506	0.0096
MCFN061	4.54	15.75	0.0172	0.16	0.63	2.42	16.735	0.59	2.965	50.01	0.0435	0.0132
MCFN062	4.17	15.96	0.0151	0.14	0.70	1.46	16.54	0.6	2.54	51.065	0.0330	0.0126
MCFN064	4.615	15.44	0.0166	0.19	0.63	1.51	18.07	0.63	3.095	49.01	0.0558	0.0142
MC1000	4.25	15.12	0.03	0.35	0.75	1.15	7.98	0.96	3.45	60.79	0.0454	0.0143
MC1001	3.4	11.86	0.03	0.69	0.51	1.27	19.95	0.83	2.88	44.28	0.0298	0.0120
MC1002	5.9	19.28	0.03	0.23	0.89	1.58	6.25	0.92	3.5	57.56	0.0436	0.0158
MC1003	4.22	15.31	0.03	0.22	0.72	1.23	8.2	1.14	3.43	60.73	0.0389	0.0144
MC1004	3.18	12.67	0.02	0.22	0.53	1.35	18.97	0.74	2.98	44.74	0.0369	0.0121
MC1005	3.3	13.37	0.03	0.38	0.52	1.46	19.15	0.66	3.1	43.64	0.0306	0.0129
MC1006	5.17	17.8	0.03	0.45	0.78	1.61	7.02	0.65	4.69	56.18	0.0504	0.0171

MC1007	3.53	12.97	0.03	0.23	0.55	1.4	18.27	0.81	3.09	46.12	0.0304	0.0130
MC1008	2.99	12.78	0.02	0.27	0.52	1.44	18.58	0.78	3.06	44.37	0.0436	0.0124
MC1009	4.21	15.23	0.03	0.24	0.74	1.19	9.86	0.99	3.34	58.92	0.0406	0.0141
MC1010	4.24	15.82	0.03	0.39	0.76	1.16	7.19	1.05	3.55	61.4	0.0443	0.0148
MC1011	4.51	15.91	0.03	0.41	0.76	1.21	8.62	0.82	3.4	57.77	0.0418	0.0146
MC1012	3.89	14.85	0.03	0.27	0.72	1.19	8.63	0.94	3.5	58.83	0.0414	0.0141
MC1013	4.33	15.28	0.03	0.2	0.77	1.22	6.56	1.08	3.4	63.95	0.0401	0.0146
MC1014	5.3	18.19	0.03	0.28	0.84	1.34	8.27	0.97	3.4	55.15	0.0411	0.0151
MC1015	4.82	18.75	0.03	0.41	0.87	1.27	8.71	0.92	3.38	55.09	0.0347	0.0143
MC1016	4.83	18.74	0.03	0.45	0.88	1.29	8.66	0.87	3.34	55.07	0.0369	0.0144
MC1017	5.81	19.36	0.03	0.28	0.89	1.55	6.81	0.85	3.42	57.45	0.0343	0.0148
MC1018	3.81	13.46	0.03	0.51	0.53	1.58	20.34	0.73	3	42.32	0.0224	0.0125
MC1019	5.35	17.24	0.03	0.35	0.79	1.49	11.75	0.63	3.38	52.07	0.0375	0.0146
MC1020	3.66	14.76	0.03	0.31	0.63	1.47	15.12	1	3.36	51.72	0.0224	0.0126
MC1021	5.03	16.96	0.03	0.27	0.78	1.53	12.42	0.83	3.25	51.06	0.0404	0.0144
MC1022	3.44	13.89	0.02	0.35	0.54	1.54	19.34	0.64	3.14	44.01	0.0320	0.0138
MC1023	3.38	13.01	0.03	0.48	0.62	1.55	15.93	0.77	3.11	49.92	0.0349	0.0134
MC1024	4.55	15.85	0.04	0.19	0.78	1.27	6.47	1.25	3.51	62.35	0.0423	0.0150
MC1025	3.13	12.19	0.03	0.46	0.53	1.27	19.83	0.73	2.84	45.06	0.0244	0.0113
MC1026	3.08	12.15	0.02	0.3	0.48	1.49	21.12	0.91	2.96	40.61	0.0444	0.0114
MC1027	4.06	15.32	0.03	0.2	0.76	1.15	8.37	0.95	3.4	60.9	0.0325	0.0137
MC1028	4.1	14.89	0.03	0.22	0.73	1.24	8.94	0.98	3.4	58.61	0.0393	0.0139
MC1029	4.03	15.26	0.03	0.26	0.75	1.12	8.11	0.88	3.42	60.75	0.0360	0.0138
MC1036	4.73	15.65	0.03	0.44	0.72	1.64	13.53	1.18	2.78	52.31	0.0359	0.0136
MC1037	4.73	15.91	0.03	0.32	0.7	1.35	14.23	0.7	2.99	48.84	0.0353	0.0133
MC1061	6.03	22.22	0.03	0.26	1.01	1.83	6.81	0.73	3.03	53.27	0.0397	0.0149
MC1081	5.5	16.8	0.04	0.49	0.78	2.62	8.25	1.12	3.8	54.7	0.0796	0.0133
MC1082	4.33	15.98	0.03	0.25	0.75	1.19	6.23	1.25	3.53	61.82	0.0437	0.0147
MC1083	4.64	12.19	0.03	0.38	0.59	1.33	16.13	0.83	1.92	48.74	0.0311	0.0055
MC1084	3.8	12.06	0.02	0.53	0.64	1.09	11.57	0.99	2.97	56.92	0.0367	0.0119
MC1086	3.39	11.82	0.02	0.34	0.5	1.4	21.08	0.78	2.86	41.1	0.0225	0.0100
MC1089	5.36	19.49	0.03	0.31	0.88	1.52	5.88	1.07	3.67	56.81	0.0394	0.0145
MC1090	5.53	18.15	0.03	0.42	0.79	1.65	10.32	0.74	3.47	53.01	0.0426	0.0148
MC1091	4.93	17.61	0.03	0.19	0.88	1.35	4.51	0.84	3.26	62.64	0.0344	0.0138
MC1093	4.98	16.8	0.02	0.26	0.77	1.64	8.18	0.76	3.25	55.7	0.0402	0.0127
MC1096	2.82	11.5	0.02	0.32	0.48	1.31	20.6	0.8	2.89	40.41	0.0377	0.0111
MC1097	3.67	11.99	0.03	0.44	0.48	1.22	27.04	0.7	2.5	35.85	0.0366	0.0113
MC1098	5.03	17.13	0.03	0.36	0.81	1.48	7	0.89	3.36	57.28	0.0400	0.0133
MC1099	6.37	21.55	0.03	0.22	0.99	1.7	7.95	0.62	2.9	53.56	0.0310	0.0145
MC1100	3.64	12.74	0.02	0.32	0.61	1.73	15.59	0.8	3.08	48.16	0.0336	0.0123
MC1102	5.19	17.09	0.03	0.22	0.87	1.41	5.6	0.74	3.24	61.12	0.0385	0.0152
MC1103	5.14	17.28	0.03	0.33	0.81	1.65	6.62	0.83	3.37	57.61	0.0404	0.0137
MC1106	4.61	16.31	0.03	0.18	0.78	1.23	6.62	1.15	3.51	62.33	0.0416	0.0151
MC1107	5.04	16.99	0.03	0.37	0.79	1.35	7.65	0.8	3.32	56.59	0.0378	0.0133
MC1108	4.36	15.49	0.03	0.2	0.78	1.16	7.33	0.96	3.36	62.02	0.0415	0.0142
MC1109	4.27	16.71	0.02	0.42	0.74	1.54	11.04	0.57	3.21	51.75	0.0403	0.0131
MC1110	4.23	13.13	0.03	0.55	0.58	1.23	22.41	0.64	2.84	38.97	0.0304	0.0125
MC1112	4.47	16.07	0.03	0.29	0.78	1.2	7.08	1.05	3.44	62.08	0.0411	0.0146
MC1113	4.63	15.94	0.03	0.21	0.77	1.38	9.17	0.83	3.23	55.73	0.0344	0.0138
MC1114	3.88	11.73	0.03	0.53	0.62	1.25	14.31	0.95	2.93	52.72	0.0288	0.0113

Th	Nb	Pb	Zr	Y	Sr	Ce	Ga	V	Zn	Cu	Ni	Cr
0.0011	0.0012	0.0024	0.0139	0.0023	0.0403	0.0054	0.0017	0.0072	0.0076	0.0015	0.0028	0.0058
0.0011	0.0012	0.0004	0.0141	0.0022	0.0367	0.0056	0.0016	0.0062	0.0076	0.0014	0.0027	0.006
0.0012	0.0011	0.0009	0.0137	0.0022	0.0340	0.0062	0.0013	0.0063	0.0079	0.0012	0.0027	0.0062
0.0013	0.0012	0.0014	0.0133	0.0023	0.0330	0.0048	0.0017	0.0065	0.0083	0.0014	0.0030	0.0058
0.0013	0.0014	0.0007	0.0156	0.0026	0.0353	0.0059	0.0019	0.0074	0.0102	0.0018	0.0032	0.0064
0.0014	0.0013	0.0021	0.0157	0.0024	0.0370	0.0064	0.0019	0.0071	0.0079	0.0016	0.0031	0.0056
0.0014	0.0013	0.0010	0.0157	0.0025	0.0385	0.0045	0.0018	0.0070	0.0091	0.0019	0.0033	0.0061
0.0011	0.0014	0.0003	0.0166	0.0020	0.0430	0.0067	0.0019	0.0077	0.0095	0.0019	0.0034	0.0068
0.0014	0.0013	0.0021	0.0154	0.0025	0.0412	0.0056	0.0020	0.0066	0.0087	0.0018	0.0031	0.0062
0.0013	0.0013	0.0006	0.0152	0.0023	0.0394	0.0050	0.0017	0.0068	0.0079	0.0014	0.0029	0.006
0.0013	0.0013	0.0008	0.0153	0.0025	0.0401	0.0066	0.0017	0.0064	0.0090	0.0018	0.0030	0.0058
0.0012	0.0013	0.0027	0.0153	0.0024	0.0443	0.0046	0.0020	0.0075	0.0085	0.0018	0.0032	0.006
0.0013	0.0013	0.0009	0.0153	0.0024	0.0428	0.0056	0.0019	0.0063	0.0085	0.0017	0.0031	0.0059
0.0012	0.0013	0.0002	0.0153	0.0019	0.0385	0.0063	0.0016	0.0074	0.0071	0.0013	0.0029	0.0065
0.0012	0.0013	0.0006	0.0152	0.0024	0.0369	0.0061	0.0017	0.0068	0.0088	0.0017	0.0031	0.0058
0.0016	0.0013	0.0013	0.0154	0.0024	0.0393	0.0058	0.0019	0.0067	0.0083	0.0016	0.0032	0.0058
0.0013	0.0013	0.0008	0.0158	0.0024	0.0400	0.0048	0.0019	0.0067	0.0087	0.0017	0.0032	0.0059
0.0013	0.0013	0.0023	0.0151	0.0024	0.0434	0.0050	0.0020	0.0072	0.0083	0.0018	0.0032	0.006
0.0013	0.0014	0.0013	0.0160	0.0025	0.0368	0.0059	0.0021	0.0073	0.0105	0.0019	0.0034	0.0063
0.0014	0.0015	0.0005	0.0178	0.0025	0.0371	0.0065	0.0020	0.0077	0.0092	0.0019	0.0035	0.0063
0.0012	0.0013	0.0002	0.0162	0.0024	0.0404	0.0065	0.0019	0.0069	0.0089	0.0017	0.0033	0.0061
0.0013	0.0013	0.0004	0.0150	0.0024	0.0363	0.0050	0.0019	0.0068	0.0092	0.0021	0.0031	0.0064
0.0012	0.0013	0.0006	0.0157	0.0025	0.0396	0.0053	0.0019	0.0073	0.0096	0.0018	0.0033	0.006
0.0013	0.0013	0.0007	0.0150	0.0025	0.0368	0.0050	0.0019	0.0071	0.0089	0.0017	0.0032	0.0059
0.0013	0.0013	0.0019	0.0154	0.0024	0.0433	0.0052	0.0019	0.0054	0.0084	0.0020	0.0032	0.0055
0.0013	0.0013	0.0025	0.0154	0.0024	0.0417	0.0061	0.0019	0.0058	0.0084	0.0017	0.0031	0.0058
0.0012	0.0013	0.0017	0.0157	0.0023	0.0367	0.0047	0.0018	0.0061	0.0082	0.0019	0.0031	0.0054
0.0014	0.0013	0.0008	0.0155	0.0024	0.0409	0.0057	0.0017	0.0063	0.0087	0.0018	0.0030	0.0061
0.0013	0.0013	0.0012	0.0156	0.0024	0.0394	0.0060	0.0018	0.0065	0.0088	0.0018	0.0031	0.0057
0.0013	0.0013	0.0002	0.0149	0.0023	0.0389	0.0059	0.0017	0.0063	0.0083	0.0016	0.0029	0.0059
0.0013	0.0013	0.0013	0.0152	0.0022	0.0382	0.0062	0.0019	0.0076	0.0086	0.0017	0.0031	0.0066
0.0013	0.0013	0.0020	0.0154	0.0024	0.0389	0.0054	0.0018	0.0073	0.0078	0.0015	0.0030	0.0057
0.0013	0.0013	0.0004	0.0159	0.0025	0.0410	0.0055	0.0018	0.0070	0.0090	0.0015	0.0031	0.006
0.0013	0.0013	0.0006	0.0161	0.0023	0.0413	0.0046	0.0018	0.0069	0.0087	0.0015	0.0032	0.0062
0.0012	0.0013	0.0004	0.0159	0.0024	0.0410	0.0041	0.0018	0.0069	0.0088	0.0016	0.0031	0.0058
0.0013	0.0013	0.0036	0.0153	0.0023	0.0411	0.0043	0.0018	0.0062	0.0084	0.0017	0.0030	0.0059
0.0014	0.0013	0.0005	0.0158	0.0024	0.0408	0.0055	0.0017	0.0070	0.0084	0.0015	0.0030	0.006
0.0013	0.0012	0.0023	0.0151	0.0023	0.0390	0.0058	0.0017	0.0066	0.0082	0.0017	0.0029	0.0051
0.0015	0.0014	0.0022	0.0155	0.0026	0.0396	0.0068	0.0020	0.0070	0.0090	0.0020	0.0033	0.0055
0.0013	0.0013	0.0013	0.0157	0.0026	0.0394	0.0057	0.0018	0.0068	0.0077	0.0015	0.0029	0.0055
0.0013	0.0013	0.0017	0.0154	0.0023	0.0377	0.0057	0.0016	0.0067	0.0085	0.0015	0.0029	0.0054
0.0011	0.0012	0.0016	0.0150	0.0024	0.0397	0.0058	0.0017	0.0061	0.0081	0.0017	0.0030	0.0056
0.0013	0.0012	0.0018	0.0142	0.0023	0.0408	0.0044	0.0018	0.0070	0.0078	0.0015	0.0029	0.0061
0.0011	0.0013	0.0009	0.0157	0.0025	0.0395	0.0052	0.0017	0.0066	0.0085	0.0017	0.003	0.0056
0.0013	0.0012	0.0015	0.0157	0.0024	0.0389	0.0056	0.0017	0.0066	0.0076	0.0015	0.0029	0.0059
0.0011	0.0013	0	0.0148	0.0021	0.0382	0.0051	0.0016	0.0077	0.0077	0.0014	0.0031	0.0069
0.0012	0.0013	0.0010	0.0155	0.0024	0.0396	0.0068	0.0017	0.0069	0.0085	0.0017	0.0032	0.0062
0.0011	0.0013	0.0009	0.0153	0.0024	0.0393	0.0052	0.0018	0.0065	0.0090	0.0018	0.0032	0.0062
0.0012	0.0013	0.0016	0.0156	0.0024	0.0387	0.0049	0.0018	0.0067	0.0088	0.0018	0.0031	0.0054
0.0013	0.0013	0.0014	0.0152	0.0024	0.0388	0.0052	0.0019	0.0068	0.0088	0.0019	0.0032	0.0058
0.0011	0.0013	0.0005	0.0151	0.0025	0.0383	0.0063	0.0019	0.0065	0.0086	0.0018	0.0032	0.0059
0.0012	0.0013	0.0007	0.0148	0.0024	0.0377	0.0059	0.0018	0.0064	0.0086	0.0018	0.0031	0.0058
0.0013	0.0013	0.0010	0.0153	0.0022	0.0382	0.0059	0.0018	0.0064	0.0087	0.0018	0.0032	0.006
0.0013	0.0013	0.0011	0.0156	0.0024	0.0395	0.0053	0.0018	0.0062	0.0083	0.0016	0.0030	0.0056
0.0009	0.0013	0.0023	0.0133	0.0025	0.0372	0.0056	0.0017	0.0070	0.0082	0.0022	0.0028	0.0064
0.0010	0.0014	0.0039	0.0160	0.0028	0.0397	0.0056	0.0019	0.0081	0.0093	0.0021	0.0029	0.0066
0.0011	0.0015	0.0015	0.0141	0.0026	0.0293	0.0054	0.0019	0.0073	0.0094	0.0021	0.0030	0.0058
0.0009	0.0013	0.0022	0.0152	0.0026	0.0362	0.0051	0.0018	0.0088	0.0081	0.0014	0.0027	0.0054
0.0013	0.0016	0.0020	0.0246	0.0027	0.0151	0.0066	0.0018	0.0080	0.0052	0.0011	0.0026	0.0060
0.0010	0.0014	0.0018	0.0138	0.0026	0.0348	0.0045	0.0019	0.0067	0.0088	0.0024	0.0031	0.0061
0.0010	0.0014	0.0019	0.0137	0.0025	0.0290	0.0051	0.0018	0.0092	0.0077	0.0017	0.0027	0.0057
0.0012	0.0016	0.0006	0.0186	0.0030	0.0378	0.0063	0.0021	0.0101	0.0090	0.0019	0.0033	0.0074
0.0011	0.0015	0.0021	0.0159	0.0027	0.0387	0.0051	0.0020	0.0079	0.0087	0.0022	0.0031	0.0061
0.0012	0.0016	0.0021	0.0195	0.0027	0.0426	0.0068	0.0019	0.0080	0.0073	0.0018	0.0030	0.0069
0.0010	0.0015	0.0023	0.0165	0.0028	0.0491	0.0051	0.0019	0.0096	0.0080	0.0020	0.0031	0.0058
0.0017	0.0013	0.0026	0.0225	0.0022	0.0180	0.0083	0.0018	0.0076	0.0084	0.0010	0.0023	0.0069
0.0013	0.0009	0.0022	0.0146	0.0018	0.0290	0.0050	0.0015	0.0064	0.0086	0.0012	0.0018	0.0053
0.0020	0.0014	0.0029	0.0214	0.0027	0.0204	0.0080	0.0023	0.0109	0.0100	0.0020	0.0034	0.0090
0.0018	0.0012	0.0027	0.0225	0.0022	0.0171	0.0079	0.0019	0.0074	0.0084	0.0009	0.0024	0.0068
0.0013	0.0010	0.0029	0.0143	0.0018	0.0261	0.0060	0.0016	0.0063	0.0094	0.0007	0.0018	0.0055
0.0011	0.0010	0.0020	0.0130	0.0017	0.0269	0.0041	0.0017	0.0065	0.0093	0.0008	0.0020	0.0057
0.0018	0.0014	0.0025	0.0210	0.0027	0.0149	0.0073	0.0021	0.0099	0.0079	0.0013	0.0031	0.0077

0.0014	0.0010	0.0023	0.0164	0.0018	0.0258	0.0055	0.0016	0.0064	0.0073	0.0009	0.0021	0.0056
0.0013	0.0010	0.0026	0.0137	0.0018	0.0282	0.0053	0.0016	0.0065	0.0090	0.0010	0.0017	0.0056
0.0018	0.0013	0.0023	0.0215	0.0023	0.0186	0.0073	0.0018	0.0077	0.0095	0.0009	0.0024	0.0068
0.0016	0.0012	0.0032	0.0221	0.0024	0.0179	0.0073	0.0019	0.0084	0.0117	0.0010	0.0025	0.0071
0.0017	0.0012	0.0031	0.0209	0.0023	0.0195	0.0067	0.0019	0.0088	0.0127	0.0012	0.0027	0.0072
0.0017	0.0013	0.0024	0.0213	0.0023	0.0198	0.0073	0.0018	0.0080	0.0097	0.0010	0.0022	0.0067
0.0018	0.0013	0.0025	0.0242	0.0025	0.0156	0.0082	0.0018	0.0078	0.0104	0.0010	0.0024	0.0071
0.0016	0.0015	0.0031	0.0206	0.0028	0.0226	0.0078	0.0022	0.0095	0.0107	0.0021	0.0035	0.0085
0.0016	0.0016	0.0031	0.0222	0.0029	0.0224	0.0083	0.0021	0.0104	0.0076	0.0019	0.0034	0.0084
0.0020	0.0016	0.0034	0.0223	0.0030	0.0227	0.0091	0.0022	0.0102	0.0073	0.0019	0.0034	0.0085
0.0016	0.0012	0.0023	0.0204	0.0028	0.0197	0.0068	0.0021	0.0111	0.0098	0.0018	0.0032	0.0089
0.0011	0.0010	0.0018	0.0123	0.0017	0.0265	0.0047	0.0015	0.0072	0.0083	0.0006	0.0019	0.0056
0.0015	0.0015	0.0030	0.0198	0.0029	0.0264	0.0074	0.0021	0.0098	0.0090	0.0017	0.0031	0.0076
0.0012	0.0012	0.0017	0.0157	0.0020	0.0199	0.0051	0.0016	0.0073	0.0069	0.0010	0.0019	0.0062
0.0016	0.0014	0.0026	0.0196	0.0028	0.0280	0.0074	0.0020	0.0095	0.0093	0.0014	0.0029	0.0075
0.0012	0.0010	0.0022	0.0134	0.0019	0.0269	0.0052	0.0017	0.0066	0.0098	0.0010	0.0021	0.0058
0.0015	0.0011	0.0012	0.0180	0.0020	0.0221	0.0058	0.0015	0.0072	0.0116	0.0008	0.0020	0.0055
0.0018	0.0013	0.0028	0.0226	0.0024	0.0155	0.0087	0.0018	0.0079	0.0105	0.0009	0.0026	0.0072
0.0011	0.0011	0.0017	0.0140	0.0016	0.0258	0.0050	0.0013	0.0060	0.0078	0.0007	0.0014	0.0052
0.0010	0.0009	0.0021	0.0125	0.0017	0.0311	0.0047	0.0015	0.0058	0.0088	0.0009	0.0019	0.0053
0.0015	0.0013	0.0025	0.0214	0.0023	0.0161	0.0079	0.0017	0.0080	0.0084	0.0024	0.0021	0.0068
0.0015	0.0013	0.0030	0.0212	0.0023	0.0188	0.0078	0.0017	0.0081	0.0092	0.0010	0.0023	0.0068
0.0015	0.0013	0.0026	0.0210	0.0023	0.0166	0.0062	0.0017	0.0082	0.0085	0.0007	0.0021	0.0069
0.0015	0.0013	0.0024	0.0189	0.0025	0.0325	0.0077	0.0019	0.0082	0.0099	0.0023	0.0030	0.0069
0.0013	0.0013	0.0025	0.0181	0.0024	0.0305	0.0075	0.0019	0.0086	0.0104	0.0017	0.0029	0.0071
0.0021	0.0018	0.0035	0.0212	0.0028	0.0215	0.0083	0.0026	0.0122	0.0107	0.0031	0.0045	0.0097
0.0016	0.0012	0.0015	0.0165	0.0023	0.0263	0.0062	0.0019	0.0105	0.0100	0.0027	0.0039	0.0081
0.0018	0.0011	0.0025	0.0220	0.0023	0.0161	0.0072	0.0018	0.0083	0.0114	0.0010	0.0025	0.0073
0.0010	0.0011	0.0022	0.0159	0.0015	0.0371	0.0033	0.0014	0.0088	0.0097	0.0012	0.0026	0.0081
0.0018	0.0010	0.0032	0.0228	0.0019	0.0186	0.0081	0.0013	0.0064	0.0055	0.0009	0.0015	0.0054
0.0009	0.0009	0.0019	0.0118	0.0016	0.0247	0.0039	0.0012	0.0057	0.0079	0.0006	0.0014	0.0052
0.0016	0.0014	0.0028	0.0191	0.0025	0.0205	0.0070	0.0020	0.0114	0.0094	0.0010	0.0033	0.0089
0.0016	0.0013	0.0028	0.0191	0.0026	0.0255	0.0062	0.0021	0.0095	0.0115	0.0023	0.0035	0.0079
0.0016	0.0014	0.0051	0.0230	0.0025	0.0139	0.0067	0.0019	0.0095	0.0082	0.0011	0.0023	0.0079
0.0017	0.0012	0.0026	0.0188	0.0022	0.0169	0.0060	0.0019	0.0088	0.0084	0.0013	0.0025	0.0075
0.0014	0.0009	0.0025	0.0126	0.0017	0.0292	0.0048	0.0014	0.0060	0.0078	0.0010	0.0017	0.0052
0.0014	0.0008	0.0013	0.0114	0.0019	0.0381	0.0029	0.0015	0.0059	0.0088	0.0023	0.0023	0.0053
0.0018	0.0013	0.0025	0.0198	0.0023	0.0182	0.0066	0.0020	0.0093	0.0090	0.0017	0.0025	0.0076
0.0020	0.0017	0.0033	0.0215	0.0029	0.0235	0.0081	0.0024	0.0118	0.0099	0.0021	0.0043	0.0093
0.0016	0.0010	0.0021	0.0163	0.0018	0.0196	0.0060	0.0016	0.0071	0.0123	0.0013	0.0021	0.0054
0.0021	0.0017	0.0029	0.0254	0.0027	0.0144	0.0088	0.0020	0.0092	0.0094	0.0013	0.0027	0.0077
0.0018	0.0013	0.0028	0.0202	0.0023	0.0176	0.0062	0.0020	0.0095	0.0095	0.0017	0.0027	0.0078
0.0020	0.0012	0.0030	0.0223	0.0023	0.0151	0.0075	0.0019	0.0084	0.0114	0.0011	0.0027	0.0072
0.0016	0.0013	0.0025	0.0195	0.0023	0.0184	0.0067	0.0019	0.0090	0.0083	0.0014	0.0024	0.0078
0.0018	0.0013	0.0028	0.0226	0.0022	0.0151	0.0078	0.0018	0.0080	0.0093	0.0010	0.0025	0.0069
0.0016	0.0014	0.0103	0.0177	0.0021	0.0304	0.0070	0.0019	0.0091	0.0082	0.0018	0.0031	0.0076
0.0017	0.0010	0.0059	0.0149	0.0017	0.0258	0.0047	0.0016	0.0066	0.0070	0.0021	0.0026	0.0057
0.0018	0.0012	0.0029	0.0218	0.0022	0.0151	0.0070	0.0019	0.0083	0.0113	0.0025	0.0031	0.0067
0.0018	0.0014	0.0030	0.0217	0.0023	0.0146	0.0091	0.0018	0.0088	0.0073	0.0011	0.0025	0.0071
0.0015	0.0010	0.0028	0.0197	0.0018	0.0209	0.0053	0.0013	0.0062	0.0064	0.0013	0.0017	0.0054

LOI
10.6003
7.0226
6.9177
10.1563
5.4646
8.7757
7.5459
8.2769
7.5952
7.0739
7.7249
11.8648
6.0799
9.5208
7.4142
9.2113
6.4804
11.3195
6.0693
12.5969
3.4853
5.7315
6.8071
6.9853
7.076
7.9706
7.5977
7.2802
7.8833
6.8841
8.5029
9.9014
3.9174
7.8837
5.5956
6.2034
6.0738
9.9391
8.0741
7.9779
7.1608
7.1608
11.5247
8.3456
7.6785
5.4567
6.1
6.3895
7.4623
7.9463
7.6584
7.9282
7.6122
7.4062
9.2670
6.8837
5.5956
6.2034
2.8833
5.8841
8.5029
2.9014
5.9706
6.5977
7.2802
4.22
13.61
2.32
3.47
14.18
13.89
4.56

13.25
15.39
4.08
3.42
4.46
5.78
2
4.21
4.04
3.96
1.6
13.13
4.91
6.57
6.2
11.8
10.11
2.31
12.86
16.49
4.26
5.87
4.16
3.2
4.79
3.8
3.87
1.92
11.53
8.24
15.97
3.22
4.07
1.96
6.66
17.98
15.34
5.28
2.59
12.18
2.88
5.46
2.17
5.88
3.28
8.81
15.06
2.92
7.08
10.98

Table 3 Click here to access/download;Table;Table 3.xls

Group		Fe_2O_3%	Al_2O_3%	MnO%	$P_2O_{5\%}$	TiO_2%	MgO%	CaO%	Na_2O%
RG(n=54)	max	5.12	16.81	0.03	0.27	0.70	2.42	27.62	1.21
	min	4.05	13.27	0.02	0.14	0.56	1.43	16.54	0.42
	mean	4.48	14.95	0.02	0.18	0.61	1.67	21.07	0,64 (0.53*)
	st.d	0.31	1.05	0.00	0.04	0.05	0.31	4.13	0,24 (0.09*)
G1 (n=10)	max	4.80	16.69	0.03	0.26	0.79	2.21	22.86	2.07
	min	3.91	14.07	0.02	0.16	0.57	1.34	17.70	0.53
	mean	4.21	15.08	0.02	0.21	0.65	1.67	20.11	0,84 (0,72*)
	st.d	0.16	0.57	0.00	0.02	0.04	0.13	0.97	0,40 (0.12*)
G1+RG (n=64)	max	5.12	16.81	0.03	0.27	0.79	2.42	27.62	2.07
	min	3.91	13.27	0.02	0.14	0.56	1.03	10.37	0.42
	mean	4.25	15.05	0.02	0.21	0.64	1.66	20.09	0.81 (0.66*)
	st.d	0.22	0.66	0.00	0.03	0.05	0.19	2.21	0.39 (0.14*)
G2 (n=10)	max	4.23	13.89	0.03	0.69	0.58	1.58	22.41	0.91
	min	2.82	11.50	0.02	0.22	0.48	1.23	18.27	0.64
	mean	3.38	12.78	0.03	0.38	0.52	1.41	19.87	0,75 (0,73*)
	st.d	0.39	0.71	0.01	0.15	0.03	0.11	1.21	0,08 (0,08*)
G3 (n=29)	max	5.90	19.49	0.04	0.45	0.89	1.65	14.23	1.25
	min	3.89	14.85	0.02	0.18	0.70	1.12	5.60	0.63
	mean	4.75	16.68	0.03	0.29	0.79	1.34	8.15	0.92 (0.92*)
	st.d	0.53	1.41	0.00	0.08	0.05	0.17	1.93	0.15 (0.16*)
G4 (n=5)	max	5.35	17.24	0.03	0.44	0.79	1.64	14.23	1.18
	min	4.27	15.65	0.02	0.27	0.70	1.35	11.04	0.57
	mean	4.82	16.49	0.03	0.36	0.75	1.51	12.59	0,78 (0.78*)
	st.d	0.36	0.61	0.00	0.06	0.03	0.09	1.16	0,22 (0,22*)

K_2O%	SiO_2%	Ba ppm	Rb ppm	Th ppm	Nb ppm	Pb ppm	Zr ppm	Y ppm	Sr ppm
3.10	51.96	570	142	12	16	39	195	30	491
2.10	39.65	330	78	9	13	6	133	25	290
2,70 (2,80*)	46.11	461	121 (121*)	10	14	21	157	27	374
0,30 (0,23*)	4.22	77	2(2*)	1	1	8	21	1	59
3.40	51.15	479	178	16	15	36	178	26	443
1.04	43.43	268	62	11	11	0	133	19	330
2,64 (3,11*)	47.17	365	123 (144*)	13	13	12	154	24	392
0,56 (0,17*)	1.20	45	1 (2)	1	1	8	7	1	22
3.4	61.75	570	178	16	16	39	246	30	491
1.04	39.65	268	62	9	11	0	133	19	151
2.65 (2.85*)	47.24	381	121 (121*)	12	13	13	156	24	386
0.53 (0.20*)	2.70	61	2(1*)	1	1	8	15	2	43
3.14	46.12	444	138	17	10	59	164	19	311
2.84	38.97	224	111	10	9	18	123	17	258
2,99 (2,99*)	42.95	338	124 (124*)	13	10	27	138	18	276
0,10 (=.10*)	2.16	64	7 (7*)	2	0	11	12	1	17
4.69	63.95	504	171	21	17	34	254	30	305
2.99	48.84	325	127	13	11	23	181	22	144
3.43 (3.43*)	57.99	399	144	17	13	28	212	25	190
0.26 (0.26*)	3.64	37	1 (1*)	2	1	3	16	2	41
3.38	52.31	404	146	16	15	103	198	29	325
2.78	48.84	353	131	13	13	24	177	21	264
3,12 (3.12*)	51.21	379	138(138*)	15	14	42	188	25	296
0,21 (0.21*)	1.26	21	6 (6*)	1	1	31	8	3	21

Ce ppm	Ga ppm	V ppm	Zn ppm	Cu ppm	Ni ppm	Cr ppm
68	21	101	94	24	33	74
45	17	67	73	14	27	54
55	19	83	85	20	29	62
7	1	11	7	3	2	6
68	21	77	105	21	35	69
41	13	54	71	12	27	51
56	18	68	85	17	31	59
7	1	5	6	2	2	3
68	21	101	105	24	35	74
41	13	54	52	11	26	51
55	18	70	85	17	31	60
7	1	8	8	2	2	4
60	17	72	98	21	26	58
41	14	58	70	6	17	52
50	16	64	85	10	20	55
5	1	4	9	4	3	2
91	23	114	127	25	35	90
60	17	74	73	7	21	67
75	19	89	96	14	27	75
8	2	11	14	5	4	7
77	21	98	104	23	31	76
70	19	82	82	14	29	69
74	20	90	94	18	30	73
2	1	6	8	3	1	3