

**A unique assemblage of Roman handmade/slow wheel-made pottery at Tamuda
(Tetouan, Morocco): provenance, production technology, and archaeological
implications**

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Abstract

A study of a 2nd century AD assemblage of handmade/slow wheel-made cooking wares, found at the Roman settlement of Tamuda (Tetouan, Morocco) is presented. Such ceramics are rare in Early-Middle Roman Imperial contexts of the western Mediterranean. A combined typological and archaeometric approach—including petrographic, mineralogical, and chemical analyses— was carried out to study this assemblage, aiming to examine the hypothesis of a local or regional provenance and to shed light on its production technology. The results indicate the existence of a diversity of products, including a fabric that was likely locally manufactured, as well as other imported fabrics that point to micro-regional distribution or trade of some of these wares. This research is a significant contribution towards a better understanding of the handmade/slow wheel-made pottery that was produced and consumed in the northern Moroccan Rif in the Roman period.

Keywords

Roman pottery; Mauretania Tingitana; northern Rif; thin-section petrography; ceramic production technology; cooking wares

1. Introduction

Studies on handmade and slow wheel-made cooking wares in Roman archaeology have been mainly focused on the Late Roman period and the Late Antiquity in general, when these wares were widely distributed and consumed throughout the Mediterranean. Some of them acquired high importance as inferred from their remarkable commercial distribution in many different and distant geographical areas. In numerous Late Antique archaeological sites of the western Mediterranean, findings of handmade or slow wheel-made cooking wares imported from areas like Sardinia, Pantelleria, Cartagena, or the Aegean, among others, have been increasingly common (Fulford & Peacock 1984; Reynolds 1995, 2010; Macias 1999; Cau 2003, 2007a, 2007b; Macias & Cau 2012). Other wares were produced locally or regionally (in the Iberian Peninsula see for example CEVPP 1991; Reynolds 1993, 2010; Macias 1999; Caballero et al. 2003; Buxeda & Cau 2005; Cau et al. 2019; Riutort et al. 2022). In the case of the Strait of Gibraltar region, Late Antique handmade or slow wheel-made cooking wares have been found at various sites on the southern Spanish coast, like Cádiz (Giles et al. 1995; 1997), Baelo Claudia (Bernal-Casasola et al. 2013a, 2016; Fantuzzi et al. 2021), Algeciras (Cau & Bernal-Casasola 2018) or Málaga (Navarro et al. 1997; Serrano 2000; Acien et al. 2003). In recent years, similar findings have started to be reported at sites located on the northern African side of the Strait, like Ceuta (Bernal-Casasola et al. 2005, 2014a; Bernal-Casasola 2007) and Tamuda in Morocco (Bernal-Casasola et al. 2022).

In clear contrast with this situation, the archaeological evidence for handmade or slow wheel-made pottery in the Early Roman period is scarce in the western Mediterranean (e.g. Peacock 1982, 75-89). Just as it happened in other territories after the Roman conquest, in the case of northern Morocco (where the Roman imperial period starts in AD 40, after the assassination of Ptolemy of Mauretania), and more generally in the Strait of Gibraltar, cooking ware assemblages tended to adopt, through either trade or local production, a variety of wheelmade forms that were more typical of the Roman culinary tradition and were widespread across the territories under Roman influence. Indeed, the archaeological evidence from sites dated to the Early and Middle Roman Empire (until the 3rd century AD) has revealed that cooking wares were normally wheelmade. The best example are those produced in Tunisia and widely distributed across the Roman world (Bonifay 2004). Wheelmade cooking wares continued to be extremely common in the Mediterranean until the Late Roman period, when there was a gradual

transition —especially in the 4th-5th centuries AD— towards the predominance of handmade and slow wheel-made wares, both imported and local/regional, in the *instrumentum domesticum* (see discussion in Macias & Cau 2012).

Even if the replacement of a handmade tradition by wheelmade cooking wares was generalized, the almost absence of handmade ware assemblages in Roman contexts dated to the Early and Middle Empire might be also partially related to a bias in the published literature. Occasional findings of handmade pottery are often interpreted as an enduring ‘indigenous’ (i.e. not Roman) production and, in some cases, are even interpreted as ‘residual’ in archaeological contexts. However, it is highly likely that handmade wares were common in various parts of the Roman world or, at least, more common than what is usually acknowledged (see discussion in Peacock 1982: 75-89). This should not be surprising if we consider that in various regions a continuation of indigenous (pre-Roman) ceramic traditions could have taken place. Handmade pottery present in the Early Roman period has been generally interpreted in this way.

In view of these considerations, the findings of handmade pottery in Roman imperial contexts prior to the Late Roman period acquire particular significance. Some examples have been reported for Mauretania Tingitana at sites like Thamusida (Camporeale 2013) and Rirha (Leclercq 2016: 179-182), and very rarely on the Spanish side of the Strait of Gibraltar (Redondo & Zamora 1998: 220-224), but an in-depth study of these wares has never been undertaken. Considering this paucity of information, the excavation in 2012 of a large pottery assemblage dated to the 2nd century AD at the Roman site of Tamuda (Tetouan, Morocco) (Fig. 1), including large quantities of handmade and possibly slow wheel-made vessels (Bernal-Casasola et al. 2014b), was particularly remarkable. Examples of handmade/slow wheel-made pottery are known at the same site from Mauretanian contexts (e.g. Sáez et al. 2013: 187; Bernal-Casasola et al. 2020: 602) and especially from Late Roman contexts (e.g. Bustamante et al. 2013: 312-313; Bernal-Casasola et al. 2022), but this was the first assemblage documented for the Early-Middle Roman Imperial period at the site except for other very occasional findings (e.g. Bustamante et al. 2013: 303). Given its exceptionality, in this paper we present a scientific analysis of this pottery assemblage, which provides a unique opportunity to gain an insight into poorly known aspects of ceramic production and consumption in Mauretania Tingitana and into the coexistence of handmade and wheelmade traditions in this Roman military camp.

The macroscopic characteristics of these wares initially suggested that they could have been produced locally and/or regionally (given the lack of known parallels in other regions), although further evidence was needed to test this hypothesis. However, at the same time, the diversity of forms, decorations, and macroscopic fabrics present within this pottery assemblage prompted consideration of the potential presence of products originating from other sites or regions. This scenario might have broader implications regarding ceramic production, technology, and cultural traditions in the northern Rif during the Roman era. For these reasons, an investigation combining typological and archaeometric approaches to the study of these wares was carried out. Instrumental analytical techniques, including petrographic, mineralogical, and chemical analyses, were applied to characterize the ceramic materials, with the aim of investigating their compositional variability as well as shedding light on their provenance and on some features of their manufacturing technology. The characterization of these wares would certainly help to address some key questions. For example, how heterogeneous were they in terms of fabric and composition? Were they locally produced? Or were there any wares traded or imported from other sites in the same region and/or abroad? Answering these questions is essential for enhancing our comprehension of pottery production models, distribution networks, and consumption patterns in Tamuda, and more broadly, in the Tingitan peninsula after the Roman conquest of the region.

2. The archaeological site of Tamuda and the Roman context under study

Morocco was a territory closely linked to Atlantic-Mediterranean economic and commercial trends beginning in the Phoenician-Punic period. It experienced significant development as a result of the Roman conquest, transforming from independent Mauretanian kingdoms into the well-known and prosperous province of Mauretania Tingitana (see Villaverde 2001). At that time, the territory was endowed with about a dozen cities —some of them pre-existing and of colonial rank— concentrated on the Atlantic coast, with Tingi (Tangier) to the north and Sala (Rabat) to the south. It also had a strategic and well-defined road network, featuring two major roads (both running north-south) that structured the entire territory, and was characterized by prosperous farming, herding, and fishing activities (Akerraz 2023). It became a key territory for Rome as the southwestern frontier of the Empire. This *limes* had a physical manifestation on the ground through about a dozen legionary and auxiliary troop camps (*castra* and *castella*),

which defended this province from the incursions of the indigenous Mauretanian tribes. These tribes were always resistant to the Roman presence from the time of conquest, as illustrated by the well-known episode of Aedemon (see Lenoir 2011). This military context is where the site under study in these pages developed.

The Mauretanian and Roman site of Tamuda (Tetouan) is located in the valley of the Martil river (Fig. 1a-b), about 15 km from where the mouth of this river meets the Mediterranean sea, and has a long occupational sequence from the 6th/5th centuries BC to the 5th century AD (Bernal-Casasola et al. 2012, 2013b, 2018, 2022). In the 1st century AD, following the Roman conquest of northern Morocco and the establishment of the Mauretania Tingitana province, a Roman military camp, or *castellum*, was constructed at this location, replacing the former Mauretanian settlement. Since 2008, several archaeological excavations have been conducted at the site by a Moroccan-Spanish team led by the University of Cádiz (Bernal-Casasola et al. 2008, 2012, 2013b, 2018, 2022).

In 2012, during the excavation of Sounding 8 at the so-called Eastern Quarter, a pottery kiln dated to the late 2nd or early 1st century BC was uncovered (Fig. 1b-c). This structure was initially used—at least during the Mauretanian period—for the production of common wares and indeterminate amphorae, and it was later reused as a lime kiln until its abandonment in the first half of the 2nd century AD (Bernal-Casasola et al. 2014b). The layers of abandonment that filled the kiln exposed evidence of a fire or other traumatic event, including plentiful charcoal, ash, and scorched pottery. This evidence might be linked to the large fire that affected the *castellum* in the mid-2nd century AD, which has been stratigraphically identified—and well dated—at the southern and western doors of the military camp (Bernal-Casasola et al. 2013b). The ceramic assemblage found in these abandonment layers (stratigraphic units SU-864, SU-865, and SU-866) included, among other ware types, various broken—but complete—tablewares of African Red Slip Ware (ARS) A, particularly the form Hayes 9, as well as glass artifacts and, interestingly, large quantities of handmade/slow wheel-made pottery. The latter are particularly important as this is the first well known and significant assemblage of this kind of pottery found in an Early-Middle Roman imperial context in northern Mauretania Tingitana. The fact that these wares were found in a closed stratigraphic context supports the reliability of their chronology, which was dated to the first half or mid-2nd century AD, that is during the Antonine era (Bernal-Casasola et al. 2014b). This chronology is much earlier than the Late Antiquity distribution of handmade/slow wheel-

made wares across the western Mediterranean, including at Tamuda (Bernal-Casasola et al. 2022).

The context of the materials found at Tamuda is significant from various perspectives. Firstly, the site constitutes a socio-economic environment of contact and hybridization, like all Roman military settlements, where —from the construction of the Roman camp during the time of Claudius— troops from various parts of the Roman world¹ coexisted with the local Mauretanian population of the Rif region. This population had inhabited the Martil river valley since at least the 6th century BC and lived in the eponymous city, which was destroyed by Rome during the provincial annexation. Exogenous material culture brought by the stationed troops would have been used alongside local crafts, including pottery, provided by the indigenous population. Furthermore, it is worth noting that Tamuda's location, just a few kilometers from the coast, facilitated active trade in all kinds of goods, as illustrated by the quantity and variety of ceramics imported from the major production centers of the Atlantic-Mediterranean region². This trade dynamic, which began centuries earlier but was greatly intensified from the Roman conquest until the abandonment of the settlement in the time of Honorius, must have had a significant impact on various communities (foreign military, local Mauretians, and heterogeneous peoples from nearby Roman cities like Tingi or Septem) and their diverse cultural and gastronomic traditions. Handmade ceramics predating the 4th century AD were not part of the usual household goods traded in Roman times, nor of the military *impedimenta*. Therefore, the presence in Tamuda of a significant assemblage of handmade or slow wheel-made pottery in a context from the 2nd century AD, alongside various exogenous imports, constitutes a notable find. This assemblage was initially interpreted as being typical for local/regional communities that likely inhabited the vicinity of the camp and who interacted with the military troops, as this tradition of non-wheel-made pottery was a distinctive feature of Mauretanian communities since at least the Recent Prehistory period.

3. The handmade/slow wheel-made pottery assemblage

¹ These troops included the Britons, as evidenced by some inscriptions (Bermejo 2015) and literary sources (such as the *Notitia Dignitatum*, XXVI, 13), which refer to the *Praefectus Alae Herculeae*.

² These wares included Italic, Gaulish, and Hispanic sigillata wares between the Julio-Claudian and the Antonine periods (Bustamante 2010); and especially African red-slip (ARS) wares, along with other finewares from workshops in southern France produced between the 3rd and 5th centuries AD (Bernal-Casasola et al. 2022).

The assemblage of handmade/slow wheel-made pottery identified in the abovementioned contexts comprised the remains of 40 fragmented vessels, which included various shapes of cooking pots and casseroles (Fig. 2a). Even if no complete profiles were found, recovered fragments indicate the presence of a wide range of forms and sizes, from small pots up to 11 cm in rim diameter to large casseroles up to 29 cm in rim diameter. Pots usually measured about 15-20 cm in rim diameter; it should be noted, however, that some pieces were so fragmented that an estimation of diameters was not always possible.

All the studied vessels appear to have been handmade or, possibly, formed with the use of a slow wheel or tournette. Their fabrics are characterized by a dark-colored (gray to black) matrix, generally grading —to a greater or lesser extent— into brown or reddish surfaces, likely because of irregular firing conditions. Vessels were mostly produced in a reducing firing atmosphere.

While the vessels lacked any surface treatment, it is noteworthy that approximately half of the assemblage displayed decoration using various decorative techniques (Fig. 2b). The most prevalent decorations were incised zigzags along the outer rim and finger impressions on either the inner or outer rim. While both forms of decoration were frequent, they were never observed together on the same vessel. Another type of decoration, less common than the others, involved the application of small clay pellets to the rim. Some of the vessels had elements designed to ease handling (Fig. 2b), such as either rounded applied elements (mamelons) or an applied horizontal cord. Only in one case was it possible to find a mamelon and decoration —incised zigzag— on the same vessel.

The lack of similar ceramic assemblages known from the same period, not only at Tamuda but also in the wider region, precludes comparisons. It is noteworthy, however, that the prevalence of handmade or slow wheel-made cooking wares at Tamuda during the Roman period is very likely indicative of a longstanding regional tradition of pottery production. This tradition can be observed in the common occurrence of handmade/slow wheel-made pots in both Mauretanian (pre-Roman) contexts and Late Roman contexts (see Bernal-Casasola et al. 2022). However, despite the general formal similarities that are to be expected in vessels designed for use over fire, such as pots or casseroles, neither the earlier (Mauretanian) nor the later (Late Roman) handmade/slow wheel-made ceramics discovered at Tamuda adhere exactly to the same tradition as those uncovered

in the 2nd century AD context. Notably, the Mauretanian ceramics lack incised or impressed decoration, unlike the vessels examined in this study. Thus, given the current available evidence, it remains difficult to determine the extent to which the decorative styles that define the ceramic assemblage analyzed in this study are connected to a longstanding local/regional (pre-Roman) tradition. Furthermore, no contemporary parallels for this assemblage have been found in northern Tingitana, and its appearance at the Roman military camp of Tamuda raises significant inquiries about the intricate relationship between indigenous traditions and the dominant Roman ceramic tradition of the area.

4. Analytical sampling and methods

Due to the variety of forms and macroscopic fabrics present within the pottery assemblage, as well as the presence of diverse decorative styles, an archaeometric study was conducted in order to determine the composition of these ceramics and, consequently, to obtain information about their provenances and manufacturing technologies. A total of 31 cooking vessels from this ceramic context were sampled for the analysis (Table 1). These vessels represent the vast majority of the handmade/slow wheel-made ceramics in the archaeological context under study and include various forms and decorative styles.

Even if the macroscopic examination of the ceramic assemblage may provide a first insight into the variability of fabrics and other technical features, both the compositional characterization of the materials and a suitable investigation of their provenance and technology require an in-depth analytical study using a combination of archaeometric techniques.

Thin-section optical microscopy (OM) is an essential technique for the identification of mineral inclusions and rock fragments in ceramic fabrics. OM data can serve as a basis for determining the geological origins of raw materials used and, therefore, the provenance of studied samples. Thin-section petrography can also provide significant information about the technological process of pottery production, including the identification of technical features such as raw material selection and processing, paste preparation, tempering, and firing (Quinn 2013; Braekmans & Degryse 2017). The mineralogical composition of ceramic materials can be further analyzed by X-ray diffraction (XRD). This technique is useful for identifying not only primary mineralogical phases in the ceramic body (that is, those minerals that were already present in the initial

clay paste, which have not been affected by the firing process), but also mineralogical phases formed during firing, as well as secondary phases formed during use and/or burial, hence providing evidence for the estimation of equivalent firing temperatures (EFT) (Roberts 1963) and the identification of post-depositional alteration and/or contamination processes (Buxeda et al. 2002; Heimann 2017). On the other hand, chemical elemental analysis, through techniques such as wavelength dispersive X-ray fluorescence (WD-XRF) spectroscopy, is also crucial for a better understanding of the compositional variability of ceramic assemblages. Chemical analyses can aid in the identification of ceramics from different production centers and/or the occurrence of different recipes for paste preparation, and can aid in assessing geochemical similarities between ceramic materials and specific geological areas.

To gain a better understanding of the compositional variability, provenance, and technology of the handmade/slow wheel-made cooking wares from Tamuda, selected ceramic samples were analyzed following this combined archaeometric approach. First, all 31 pottery samples were examined by means of thin-section OM for their petrographic-mineralogical characterization. Second, 16 of those samples were further examined through WD-XRF spectroscopy for their elemental characterization and by XRD for additional information on their mineralogical composition (Table 1).

OM petrographic-mineralogical analysis of thin sections was carried out using an Olympus BX41 polarizing microscope at magnifications between $\times 20$ and $\times 200$. Ceramic fabrics were grouped and described based on similarities in their inclusions, matrix, and microstructure, following an adjusted version of the methodology proposed by Whitbread (1989, 1995) and Quinn (2013).

The mineralogical composition of the ceramics was further examined by powder XRD. Measurements were taken using a PANalytical X'Pert PRO MPD alpha 1 diffractometer, working with the Cu K α radiation ($\lambda = 1.5406 \text{ \AA}$). Spectra were taken from 5 to $80^\circ 2\theta$, using a step-size of $0.026^\circ 2\theta$ and a step time of 47.5 s . Crystalline phases were examined using the HighScore Plus software by PANalytical, which includes the Joint Committee of Powder Diffraction Standards (JCPDS) data bank. Based on the mineral phases identified in each diffractogram, an estimation of EFTs was carried out (e.g. Maggetti 1982; Riccardi et al. 1999; Cultrone et al. 2001; Cau 2003; Maritan et al. 2006).

WD-XRF elemental analysis was performed using a PANalytical-Axios PW 4400/40 spectrometer. Fused beads were prepared for the determination of major and

minor elements, and pressed powdered pellets were used to determine trace elements (for the analytical routine, see Buxeda et al. 2003). A total of 25 elements (Fe_2O_3 , Al_2O_3 , MnO , P_2O_5 , TiO_2 , MgO , CaO , Na_2O , K_2O , SiO_2 , Ba, Rb, Th, Nb, Pb, Zr, Y, Sr, Ce, Ga, V, Zn, Cu, Ni, and Cr) were quantified using a calibration line performed with 60 International Geological Standards (Hein *et al.* 2002). The loss on ignition was calculated by heating 0.3 g of dried specimen at 950°C for 3 hr. For the multivariate statistical treatment, the elemental concentrations were transformed into additive log-ratios (alr), following the methodology proposed by Aitchison (1986, 1992) and Buxeda (1999).

5. Results

5.1. Petrographic-mineralogical analysis

Thin-section petrography revealed that the majority of the samples (29 of 31: 94%) can be categorized into two main fabric groups, mainly distinguishable from each other by the nature of their inclusions. Fabric Group 1 has ‘Argillaceous rock fragments’ and Fabric Group 2 has ‘Acidic metamorphic rocks’. Only two samples showed a different fabric (Fabric Group 3 with ‘Quartz and chert’) in thin section (Table 2; Figs. 3, 4).

Fabric Group 1 is characterized by the presence of abundant coarse fragments of fine-grained, clastic sedimentary rocks, generally claystones, which in some cases exhibit fissility (shales). Most of the samples ($n = 12$) in this fabric group show the same fabric (Fabric 1.1: Table 2; Fig. 3a-c), given their remarkable similarities in texture and composition. A few samples included in Fabric Group 1 revealed the presence of other slightly distinct fabrics in thin section (Fabrics 1.2 and 1.3: Table 2; Fig. 3e-f). The results of XRD analysis indicate that the ceramics in this group were fired at temperatures between 750 and 850 °C under reducing conditions, except for sample TAM-20 that showed evidence for high firing temperatures, likely over 950/1000 °C (Table 2; Fig. 5a).

The other major petrographic group identified through OM analysis is Fabric Group 2 ($n = 14$, see Table 2), which is characterized by the dominant presence of coarse fragments derived from acidic metamorphic rocks, especially quartzite (Fig. 4a-d). All samples in this group showed the same fabric (Fabric 2), which points to a common provenance area. The association of mineral phases observed from XRD analysis indicates that all the samples of this fabric were fired at temperatures between 750 and 850/900 °C under reducing or, more rarely, oxidizing conditions (Table 2; Fig. 5b).

Fabric Group 3, 'Quartz and chert', is not well represented in the assemblage under study, as it was only detected in two samples which exhibited very similar thin sections (Table 2; Fig. 4e-f). The mineral phases identified by XRD suggests that these ceramics were fired at temperatures not higher than 850 °C (Table 2; Fig. 5c).

5.2. Elemental analysis

A first assessment of the normalized elemental data for the 16 ceramic samples analyzed by WD-XRF (Table 3) reveals that the two main fabrics defined from thin-section petrography (Fabrics 1.1 and 2) showed well-differentiated elemental compositions, with clear differences in the concentrations of various major, minor, and trace elements.

Fabric 1.1 is characterized by a calcareous composition (CaO 6-9%), unlike the rest of the samples in the data set which are low calcareous (CaO \leq 2%). These data are consistent with the presence of frequent carbonate inclusions in this fabric, as observed in thin section. Fabric 1.1 also shows a relatively high content in Fe₂O₃ (7-8%), TiO₂ (1.0-1.1%) and Al₂O₃ (19-22%), and low SiO₂ (56-61%). Conversely, the other main fabric identified from OM analysis, Fabric 2, is characterized by low percentages of CaO (0.7-1.4%), TiO₂ (0.5%), K₂O (1.1-1.9%), MnO (0.01-0.02%), and MgO (0.7-0.9%), as well as by relatively high Na₂O (1.2-1.9%) and SiO₂ (69-77%), the latter being clearly associated with the high abundance of quartz-rich inclusions observed in thin section in this fabric. In addition, remarkable differences can also be observed between these two main fabrics (1.1 and 2) in the concentrations of trace elements such as Ce, Cr, Nb, Ni, Rb, Sr, V, and Zr (Table 3).

Interestingly, some of the samples in Fabric 2 (TAM-11 to TAM-13) reveal much higher percentages of Fe₂O₃ and Al₂O₃, and lower of SiO₂, than the other samples in the same fabric (Table 3). These three samples also show differences in trace element composition compared with the rest of the samples in Fabric 2.

Calculation of the Compositional Variation Matrix or CVM (Aitchison 1986; Buxeda 1999; Buxeda & Kilikoglou 2003) provided more details about the elemental variability of the data set. A high total variation (vt) value was obtained (2.77), indicating the polygenic origin of the assemblage. According to the CVM, there are eight elements that explain more than 50% of the variability in this data set; these are CaO ($\tau_i = 17.09$), Na₂O ($\tau_i = 16.69$), MnO ($\tau_i = 10.85$), Pb ($\tau_i = 7.41$), P₂O₅ ($\tau_i = 7.11$), SiO₂ ($\tau_i = 6.17$), Ce ($\tau_i = 5.94$), and Ni ($\tau_i = 5.68$). However, variations in some of these elements,

especially P_2O_5 and Pb, should be taken with caution since these elements are usually affected by problems of alteration/contamination in ceramics. For that reason, those two elements were excluded from the multivariate statistical treatment of these data. As for the high variability in CaO, Na_2O , MnO, SiO_2 , Ni and Ce, this must be related to the differences observed in elemental composition between samples in Fabric 1.1 and Fabric 2, as commented above.

Cluster analysis (CA) of the alr transformed elemental concentrations allowed for a better examination of this variability. The cluster tree shows the presence of two main chemical groups, which are equivalent to the petrographic Fabrics 1.1 and 2 identified in thin section (Fig. 6a). Similar conclusions can be drawn from principal component analysis (PCA) based on the same alr transformed data, where the first principal component, PC1, is dominated by CaO, Na_2O , and MnO, whereas PC2 is dominated by CaO, Sr, and Ni, and PC3 by Na_2O , Ba, Cu, and K_2O . The biplots PC1 vs PC2 and PC1 vs PC3 (Fig. 6b) illustrate the variations related to these elements and show a similar division of the data set to that obtained from CA.

In the case of Fabric 2, two chemical subgroups may be differentiated from CA and PCA, one of them (2A) including four samples (TAM-22, TAM-32, TAM-34, and TAM-39), while the other one (2B) is formed by samples TAM-11 to TAM-13. As discussed before, these two subgroups of samples within Fabric 2 present important differences to each other regarding the concentrations of various major, minor, and trace elements (Table 3). However, no significant differences were observed in thin section between the samples of Fabric 2 that could account for these differences in elemental composition.

A third cluster observed from CA (Fig. 6a) comprises two samples (TAM-15 and TAM-41) which are heterogeneous in terms of petrographic fabric (Fabrics 1.3 and 3, respectively) and whose elemental compositions also present important differences to each other and to the rest of the assemblage (Table 3). No chemical data are available for Fabric 1.2, as the only sample in this fabric, TAM-19, could not be analyzed by WD-XRF due to its small sample size.

6. Provenance of the ceramics

The combined petrographic, mineralogical, and chemical analysis of the ceramics indicates the existence of a diversity of fabrics and products, and provides new clues to

interpreting the macroscopic variability of the ceramic fabrics. Two main petrographic fabrics were identified, Fabrics 1.1 and 2, which also showed well differentiated elemental compositions, as well as a few other fabrics poorly represented in the assemblage (Fabrics 1.2, 1.3, and 3).

In order to examine the hypothesis of local or regional provenance for these handmade/slow wheel-made wares, comparison with the geological background of the area of Tetouan is essential. This area is located in the northern Moroccan Rif, which shares geological characteristics with the southern Spanish coast of the Strait of Gibraltar, in the so-called Gibraltar (or Betic-Rif) Arc (Didon et al. 1973; Negro et al. 2006; Chalouan et al. 2008). As for the site of Tamuda in particular, in addition to the Quaternary deposits related to the Martil river basin, the site is also very close to Pliocene marls as well as to outcrops of the Dorsale Calcaire (Calcareous Range), the Maghrebien Flysch nappes, and the External Zones of the Gibraltar Arc (Fig. 7) (Benmakhlouf & Chalouan 1995; Hlila 2009; El Kharim 2012). For this reason, the local geology is predominantly sedimentary, and a variety of marls, limestones, dolomites, shales, sandstones, and clays can be found in the surroundings of the site. In addition, a few kilometers eastwards, downriver, it is possible to find outcrops of low-grade metamorphic rocks from the Ghomaride complex of the Internal Zones of the Gibraltar Arc, while outcrops of medium-high-grade metamorphic rocks of the Sebti complex are located further northeast (Fig. 7) (Chalouan et al. 2008; El Kharim 2012). It is worth mentioning that various clay deposits are available around Tetouan and for some of them there is evidence for their use in ceramic industry in different historical periods (El Ouahabi et al. 2014a, 2014b).

Given this geological setting, the petrographic composition of Fabric 1.1 —rich in argillaceous rock fragments— may be compatible with the hypothesis of a local provenance in Tamuda, although a wider regional provenance could be possible as well considering the occurrence of similar geological formations along the northern Tingitan peninsula (Chalouan et al. 2008; Hlila 2009) and even on the Spanish side of the Strait. A possible indicator of a local provenance for Fabric 1.1 is the presence of a very similar petrographic fabric in most of the handmade or slow wheel-made cooking wares found in a Late Roman context dated to the 5th century AD at Tamuda (Bernal-Casasola et al. 2022), which could suggest the continuity of a similar tradition of pottery-making at the site or in the area. In any case, even if the hypothesis of local provenance cannot be fully verified in the light of the available evidence, there are some other indicators to suggest

at least a regional provenance for this main fabric. Here we can mention not only its high frequency in the assemblage of Roman handmade/slow wheel-made wares analyzed, but also the fact that no similar fabrics or wares are known for the same period in the Strait of Gibraltar region or, broadly speaking, in the western Mediterranean. The fabric is also different to the various fabrics of handmade or slow wheel-made cooking wares from later periods (i.e. Late Antiquity) that were widely distributed throughout the Mediterranean (see Fulford & Peacock 1984; Reynolds 1993; Cau 2007a, 2007b).

As concerns the provenance of the other main fabric identified in this study, Fabric 2, the petrographic composition —rich in acidic metamorphic rocks— points to a regional rather than a local provenance. In this fabric, the predominance of inclusions derived from quartzite and —to a lesser extent— metagranitoid or gneiss suggests the use of raw materials derived from the Sebtides units of the Gibraltar Arc. Interestingly, similar petrographic fabrics have been reported in Proto-historic and Late Roman handmade pottery from Ceuta (Cau et al. 2010; Fantuzzi et al. in press), which could be associated with the abundant outcrops of acidic metamorphic rocks in the area of Monte Hacho (Chamorro & Nieto 1989). Even if this would be a plausible hypothesis for the origin of Fabric 2, a provenance in other parts of the Mediterranean coast of the northern Rif cannot be discarded on a strictly geological basis, given the wide distribution of the Sebtide complex in the region (Fig. 7).

Besides these two main fabrics, a few other less common fabrics were identified in the assemblage of Roman handmade/slow wheel-made wares from Tamuda. Based on the available evidence, it is not possible to ascertain whether the vessels with these fabrics were products from the area of Tamuda or imported from other sites in the Strait of Gibraltar region or elsewhere. In the case of Fabrics 1.2 and 1.3, partial similarities with the main Fabric 1.1 —especially regarding the abundant inclusions of argillaceous rock fragments— may suggest a likely origin in the same (or a nearby) area as Fabric 1.1. However, the common presence of quartzite fragments in Fabrics 1.2 and 1.3, among other particularities already described, would indicate the use of different raw materials that include metamorphic contributions, thus pointing to regional rather than local provenances for these two fabrics. As for Fabric 3, its petrographic composition largely suggests a predominantly quartz-rich sedimentary source, which might be compatible with either a local or a regional provenance.

7. Production technology

The characterization of handmade/slow wheel-made wares from Tamuda through combined petrographic, mineralogical, and elemental analyses not only provides evidence for their likely provenance areas, but also offers important data for a better understanding of their manufacturing technologies.

It is true that the lack of certainty about the provenance of the fabrics may prevent drawing conclusions about some technological aspects, particularly those related to raw material selection and processing, as the exact sources of raw materials and the ways in which these were treated by the ancient potters is currently unknown. In any case, it is possible to highlight that the fabrics identified in this study are generally characterized by a bimodal grain size distribution of inclusions, with abundant coarse fractions. This feature might suggest intentional addition of temper by the potters, however we should not exclude as an alternative hypothesis that these coarse-grained inclusions were naturally occurring particles in the raw clayey sediments, a possibility that needs to be tested in future studies through sampling local and regional clays. In either of the two cases, it seems evident that the potters were intending to obtain a final product with a fabric containing abundant coarse-grained, non-plastic inclusions.

The various fabrics identified in this study, which are clearly different than each other in terms of their petrographic and elemental compositions, were the result of using different raw materials. Some fabric variations could be also related to varied paste recipes. The differences in the raw materials used may have been associated with distinct provenance areas for each fabric, and could also have had technological implications. In cooking wares whose intended function was to be used in direct contact with fire, as is presumably the case with the handmade/slow wheel-made wares analyzed in this study, previous studies have shown that sometimes the use of low calcareous clay pastes may be advantageous for improving heat conductivity and thermal shock resistance during the cooking process. This is the case especially when they were fired at temperatures neither too low nor too high —about 750-850 °C— in order to have also high strength and good resistance to mechanical stresses (Picon 1995; Tite et al. 2001; Hein et al. 2008; Müller et al. 2014; Müller 2016; Travé et al. 2019). In this regard, it is remarkable that one of the main fabrics identified in handmade/slow wheel-made wares from Tamuda, Fabric 1.1, contained common carbonate inclusions in both the coarse and the fine fraction as evidenced by OM (although CaO percentages, according to WD-XRF results, were not actually so high, generally 6-9%, thus indicating that a slightly calcareous clay paste was

used for this fabric). Common carbonate inclusions have also been found in Fabric 1.2, observed in only one sample from Tamuda (Table 2). Vessels made of calcareous clay pastes could have good resistance to thermal shock when fired at temperatures below 700 °C, but at the expense of having low strength and poor mechanical shock resistance. Thus they may be unsuitable for cooking purposes when fired at >900 °C (Picon 1995; Travé et al. 2019). In the case of cooking wares related to Fabric 1.1, which were made of slightly calcareous clay pastes and (according to XRD) were almost always fired at temperatures of 750-850 °C, it is likely that these technical choices may be related to potters intentionally producing cooking wares with a suitable balance between thermal and mechanical shock resistance. The only sample in Fabric 1.1 which seems to have been unsuitable for cooking purposes was TAM-20, which was fired at high temperatures ($\geq 950/1000$ °C) and thus likely had very poor resistance to thermal shock and low toughness. Interestingly, this vessel was quite different in shape compared to the rest of the assemblage (Figs. 8, 9), which may suggest that it had a different function.

In the case of vessels with Fabric 2, which have low calcareous composition and abundant coarse quartz inclusions (see Kilikoglou et al. 1995, 1998; Müller 2016 on the use of quartz-rich coarse inclusions in cooking wares), firing temperatures between 750-850/900 °C could have helped potters to produce wares with an optimal balance between thermal and physical shock resistance (Travé et al. 2019). If a local provenance for Fabric 1.1 is confirmed, these technological considerations may help to explain the coexistence in Tamuda of local cooking wares with Fabric 2 pots of perhaps even higher quality for cooking purposes imported from other regional sites. Fabric 2 is in fact the predominant fabric in the analyzed ceramic assemblage (Table 2).

As regards the firing process, it seems evident that the temperatures at which the ceramics were fired would have some relation to the nature of the raw materials used, the characteristics of the clay paste (including the coarse non-plastic inclusions) and, of course, the intended function of the wares, as discussed above. In addition to the data obtained about firing temperatures, the study of the handmade/slow wheel-made wares from Tamuda also shed light on their firing atmospheres. The macroscopic examination of the ceramic fabrics at fresh break (Fig. 10) revealed that they tend to present a dark (gray-black) color in the core, often with a lighter (reddish or brown) color towards the surfaces of the vessel; the same heterogeneities related to core-margin color differentiation were observed in thin section analysis. These data indicate that the ceramics were fired mainly in a reducing atmosphere, but most likely in irregular firings,

in which oxidation was practically spontaneous. Further evidence was provided by XRD analysis, as the common presence of maghemite —or, in sample TAM-20, hercynite— indicates a reducing firing atmosphere (Cau 2003; Maritan 2004; Travé et al. 2019), while only in a few cases the occurrence of hematite peaks may suggest firing under oxidizing conditions.

Besides raw material selection and processing, paste preparation and firing, there are other technological aspects linked to the *chaîne opératoire* (Lemonnier 1976; Rye 1981; Rice 1987; Sillar & Tite 2000; Quinn 2013; Roux 2019) that should be mentioned, such as forming and finishing techniques as well as the relation of those techniques to each of the fabrics identified in this study. The vessels analyzed seem to be handmade or possibly shaped using a slow wheel. Evidence for the use of coils was observed in some of the samples from the two main fabrics identified in this study, Fabrics 1.1 and 2. A wide variety of forms of cooking pots and —to a lesser degree— casseroles was produced, and this diversified typological repertoire can be found in both of these two main fabrics (Figs. 8, 9). As regards finishing techniques, macroscopic examination reveals that the vessels in these two fabrics generally show rough surfaces, except for signs of a slight smoothing in some examples, but perhaps the most remarkable feature is the common presence of incised, finger-impressed or, more rarely, applied decoration (Fig. 2). It is important to mention that the combined macroscopic and analytical study of the ceramics shows an evident relationship between fabrics and decorative techniques or styles (Figs. 8, 9). The vessels included in Fabric 1.1 usually have finger-impressed decoration on the rim (either the outer or the inner rim), with this decorative pattern being present on a variety of ceramic shapes (Fig. 8). In other rare cases, the pots in Fabric 1.1 can show small, applied pellets, or —in one case— incised decoration in zigzag on the outer rim. Conversely, the various forms of cooking wares in Fabric 2 commonly have incised zigzags on the outer rim, this being the only type of decoration observed in relation to this fabric (Fig. 9). The only sample in Fabric 1.2, TAM-19, shows a combination of small finger impressions on the lip, and small, applied pellets on the outer rim; these types of decorations may suggest some kind of relationship between this fabric and Fabric 1.1. The few vessels in Fabrics 1.3 and 3 do not have any clearly decorative elements. On the other hand, as regards the presence of applied elements for handling the cooking pots, again a relationship to ceramic fabric can be observed. The four vessels showing rounded applied elements (mamelons) belong to Fabric 2, while the two pots with applied horizontal cord or handle on the outer rim are the only samples included in Fabric 1.3.

In summary, the results show that each of the fabrics identified in the handmade/slow wheel-made pottery assemblage from Tamuda are different from each other not only in their compositional characteristics and, most likely, their provenance, but also in some aspects of their manufacturing technologies. Some decisions made by potters, such as which types of decorations to employ, are not necessarily related to functional advantages.

8. Conclusions

The cooking wares from Tamuda analyzed in this study are especially important for constituting the first significant published assemblage of handmade or slow wheel-made pottery known so far for the Early-Middle Roman Empire in the Strait of Gibraltar region, and one of the rare examples known in the western Mediterranean world prior to the wider diffusion of this class of pottery in Late Antiquity. Scientific analysis of these wares yielded very important results that reveal the existence of a diversity of fabrics and production zones. Even if the available evidence does not allow for a precise provenance determination of these fabrics, this analysis revealed the coexistence of two main groups of handmade or slow wheel-made cooking wares, as well as a series of less represented fabrics, with compositional, technical, and stylistic differences between them. For one of the main groups of wares, Fabric 1.1, there are indicators of a possible local provenance, while for the other main group of samples, related to Fabric 2, a regional provenance along the Mediterranean coast of the northern Rif can be proposed. Local production can be excluded based on its petrographic composition. On the other hand, Fabrics 1.2, 1.3, and 3, each represented by one or two samples only, may be associated with other local/regional products.

In summary, the results reveal that the handmade or slow wheel-made wares could not only be locally produced, but some of them may have been imported from other regional sites in northern Mauretania Tingitana. Production of handmade wares in the Roman world has been generally associated with local household production (see discussion in Peacock 1982, 75-89), although they could also have been transported some distance and traded, as has been clearly demonstrated by previous studies of various Late Roman cooking wares (e.g. Fulford & Peacock 1984; Reynolds 1993; Cau 2003). Little is known so far about these issues for the Early and Middle Roman Imperial periods, but these findings from Tamuda seem to show that at least a micro-regional distribution or

trade of some of these wares could have taken place, likely in coexistence with locally made wares. This should not be totally surprising, if we consider that these handmade or slow wheel-made cooking wares were found in archaeological contexts where most of the pottery was imported —especially from Tunisia and southern Spain—, a trend that is also observed in other ceramic assemblages from the same period at the site (e.g. Bernal-Casasola et al. 2008, 2012, 2014b). In any case, the high frequency of handmade or slow wheel-made cooking wares of Fabric 2 in Tamuda, produced elsewhere in the region, could be related to their technological properties. They seem to be suitable vessels for cooking, capable of maintaining an optimal balance between thermal and mechanical shock resistance, possibly more optimal than in the case of (local?) Fabric 1.1, as discussed before. Of course, other factors (e.g. economic, cultural, etc.) not necessarily linked to technological advantages may also account for this high frequency of various regional wares, whose interpretation is far from clear based on the available evidence, at Tamuda. In this regard, it is worth bearing in mind that this Roman military camp was a place of contact and hybridization, where coexistence with the indigenous Mauretanian communities could have promoted both commercial interactions and the development of a mix of culinary and pottery traditions. In this context, the Roman presence in the area could also have increased interactions over long distances, facilitating the arrival of regional imports such as the Fabric 2 cooking wares to Tamuda.

The lack of similar assemblages of handmade or slow wheel-made pottery in the entire region for the same period is a notable constraint in terms of drawing further conclusions. It is evident that new findings will need to be investigated in depth by combining traditional approaches (i.e. typological, stylistic, etc.) with scientific analyses in order to gain as much information as possible about aspects like provenance and technology. This research will be essential to better understanding the ways in which these wares were produced, distributed, and consumed in the northern Moroccan Rif and, broadly speaking, the western Mediterranean during the Roman Imperial period. The present study is a first step towards this objective, and the evidence obtained, including the coexistence of a variety of handmade/slow wheel-made wares at Tamuda and the likely presence of a regional trade for some of these wares, offers new insights into patterns of production and consumption at the site and reveals a complex scenario which needs to be further investigated in future studies on a wider regional scale.

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Figures

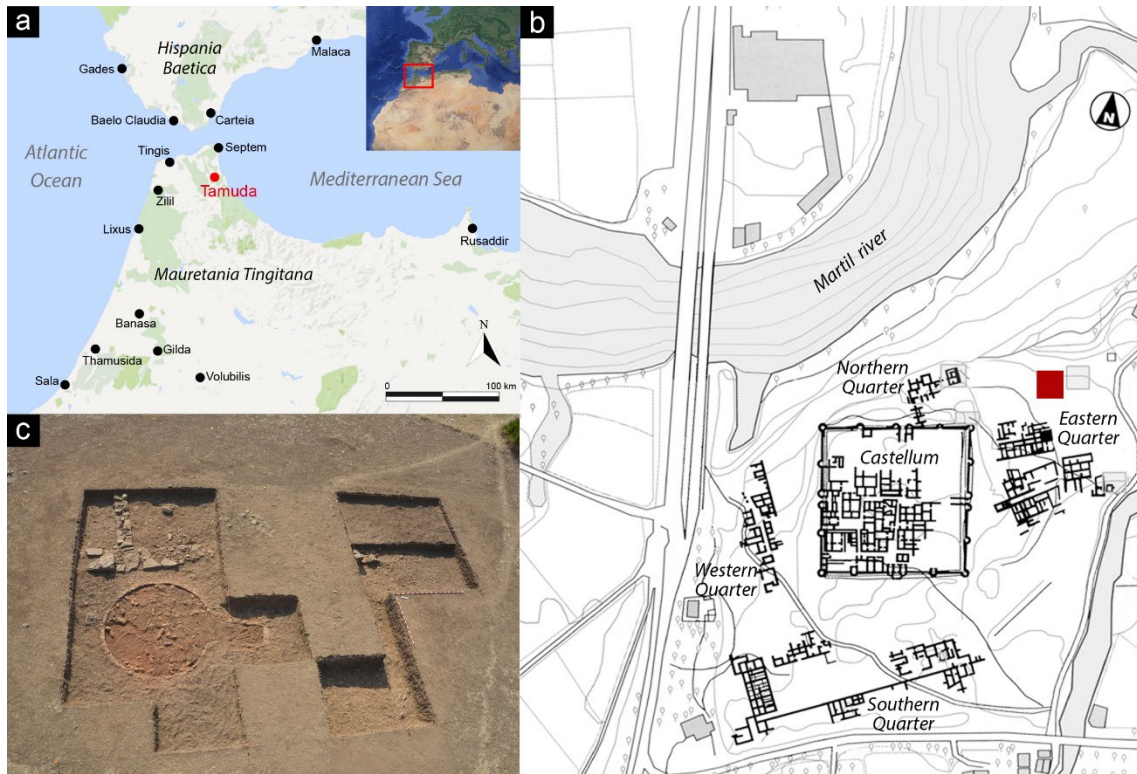


Figure 1. (a) Location of Tamuda in the context of Mauretania Tingitana and the Strait of Gibraltar region. (b) Plan of the site, with indication of Sounding 8 (red square), where the 2nd century AD context was documented. (c) Detail of the excavations at Sounding 8

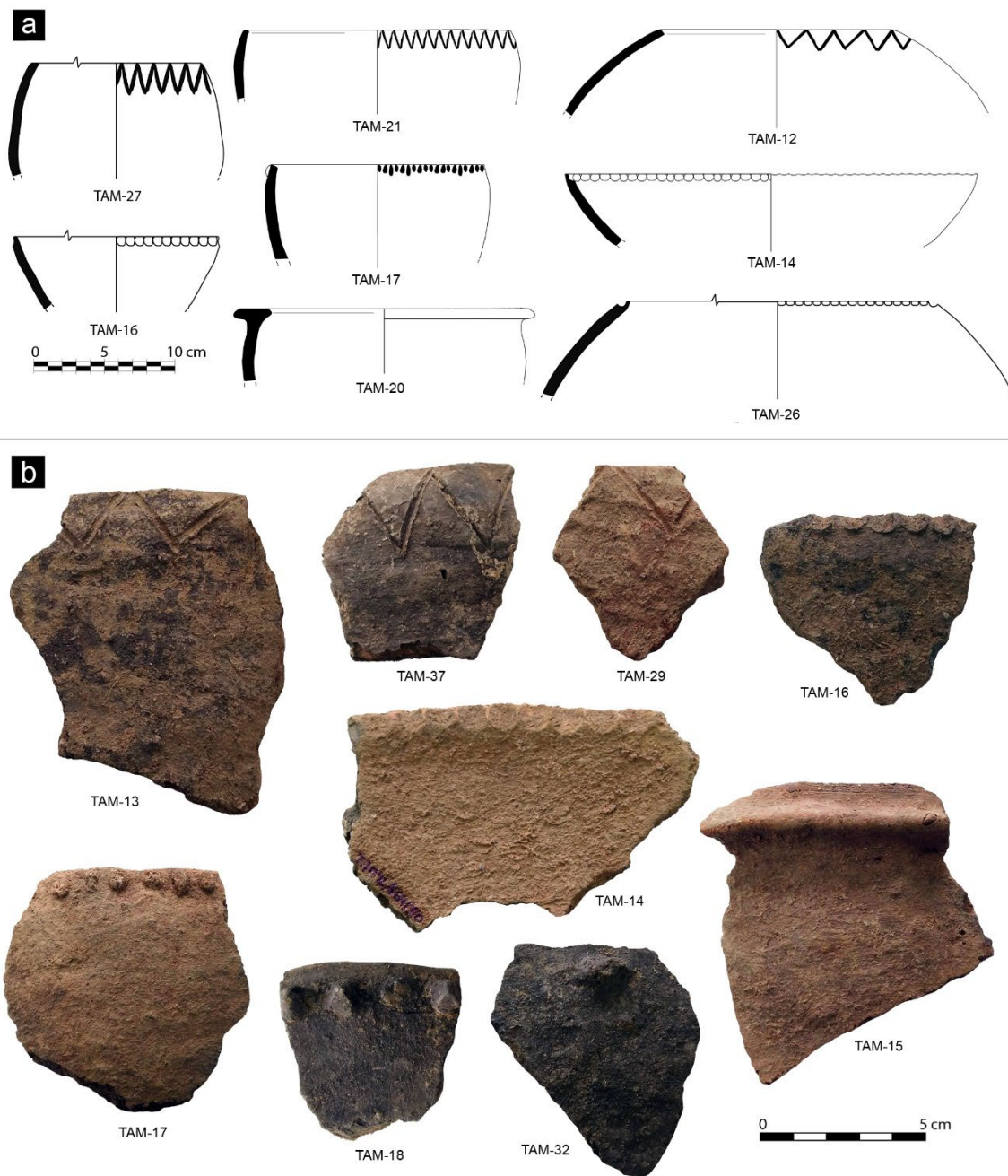


Figure 2. (a) Illustrations of various forms of cooking pots and casseroles found in the handmade or slow wheel-made pottery assemblage from Tamuda. (b) Photographs of some of the pottery samples showing a variety of decorative techniques and elements designed to better handle the vessel: incised zigzags (TAM-13, TAM-29, TAM-37), finger impressions on the outer (TAM-16) or inner (TAM-14) rim; small, applied pellets (TAM-17, TAM-18); applied mamelon (TAM-32); applied horizontal cord (TAM-15)

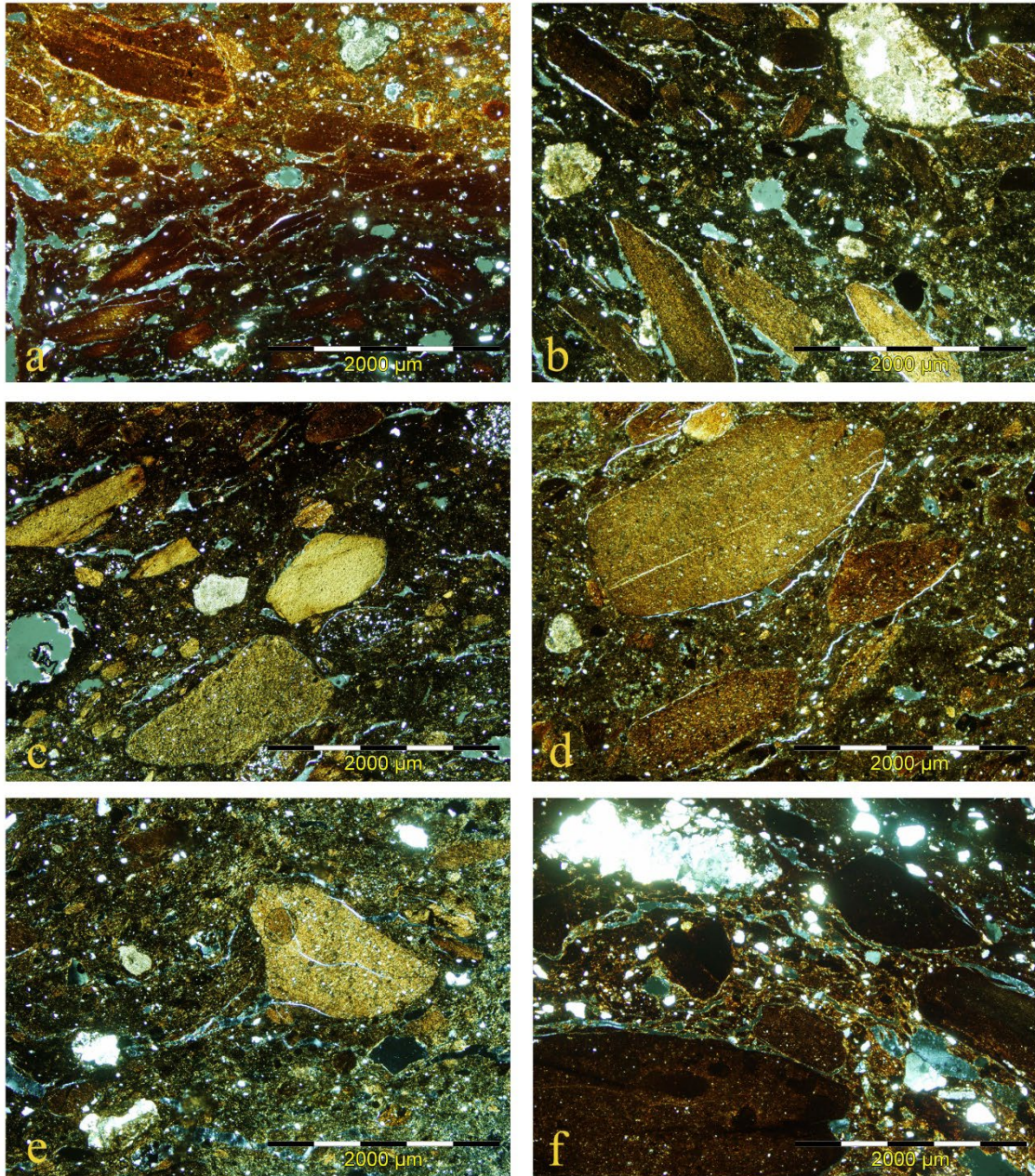


Figure 3. Petrographic Fabric Group 1: photomicrographs of thin sections, taken under crossed polars at 40x. (a-c) Fabric 1.1, samples TAM-14 (a), TAM-16 (b), TAM-18 (c) and TAM-26 (d); (e) Fabric 1.2, sample TAM-19; (f) Fabric 1.3, sample TAM-28

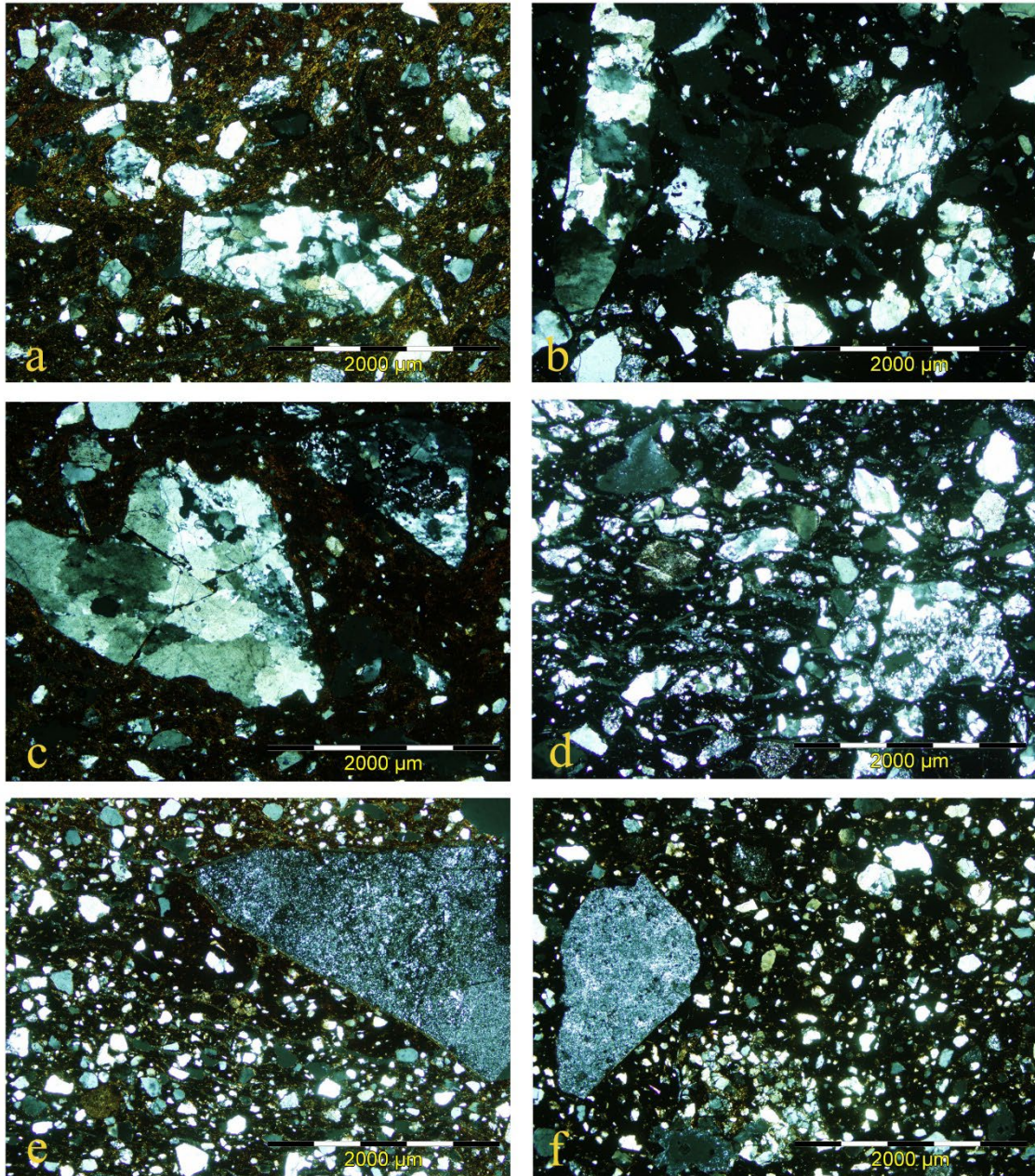


Figure 4. Petrographic Fabrics 2 (a-d) and 3 (e-f): photomicrographs of thin sections, taken under crossed polars at 40x. Samples TAM-22 (a), TAM-24 (b), TAM-29 (c), TAM-30 (d), TAM-40 (e), and TAM-41 (f)

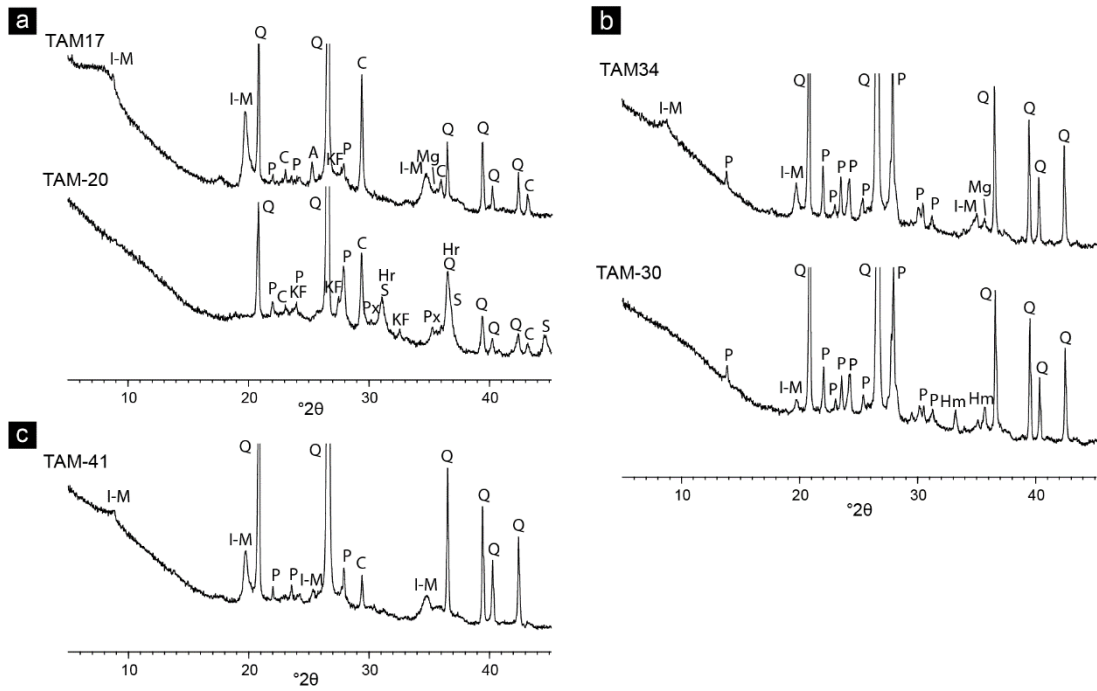


Figure 5. XRD spectra for representative samples from each of the main fabrics. Abbreviations for minerals: Q, quartz; P, plagioclase; KF, alkali feldspar; C, calcite; I-M, illite-muscovite; Mg, maghemite; A, anatase; Px, pyroxene; S, spinel; Hr, hercynite; Hm, hematite

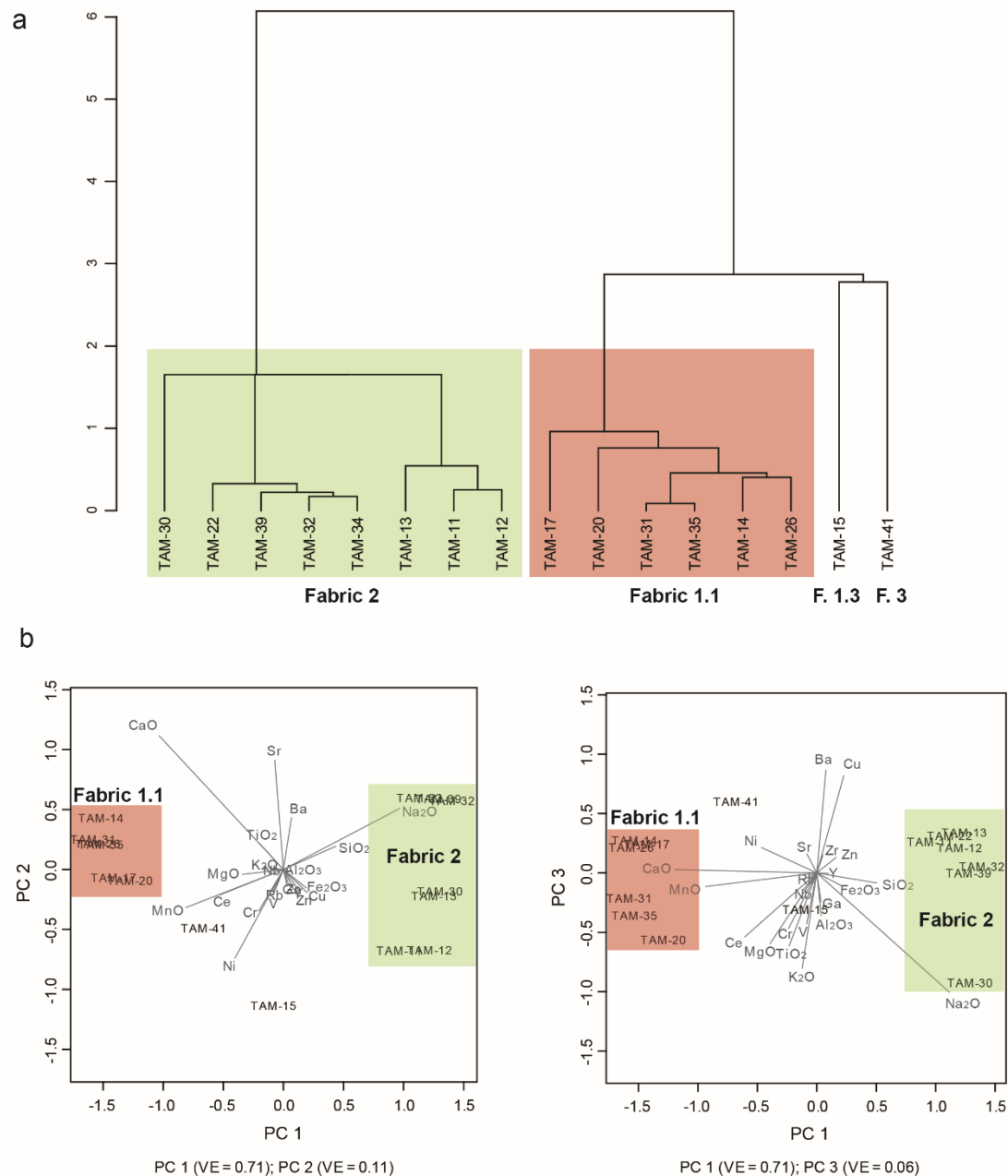


Figure 6. (a) Dendrogram from cluster analysis (CA) based on WD-XRF elemental data of 16 handmade/slow wheel-made pottery samples from Tamuda; the analysis was performed using the centroid agglomerative method and squared Euclidean distance, and it was based on the alr transformed subcomposition Fe₂O₃, MnO, TiO₂, CaO, K₂O, SiO₂, Al₂O₃, MgO, Na₂O, Ba, Ce, Cr, Cu, Ga, Nb, Ni, Rb, Sr, V, Y, Zn, and Zr, using Th as divisor. (b) Principal component analysis (PCA) based on the same alr transformed subcomposition as the CA: plots PC1 vs PC2, and PC1 vs PC3. The first three principal components (PC1, PC2, and PC3) account for 71%, 11%, and 6% of the total variance, respectively

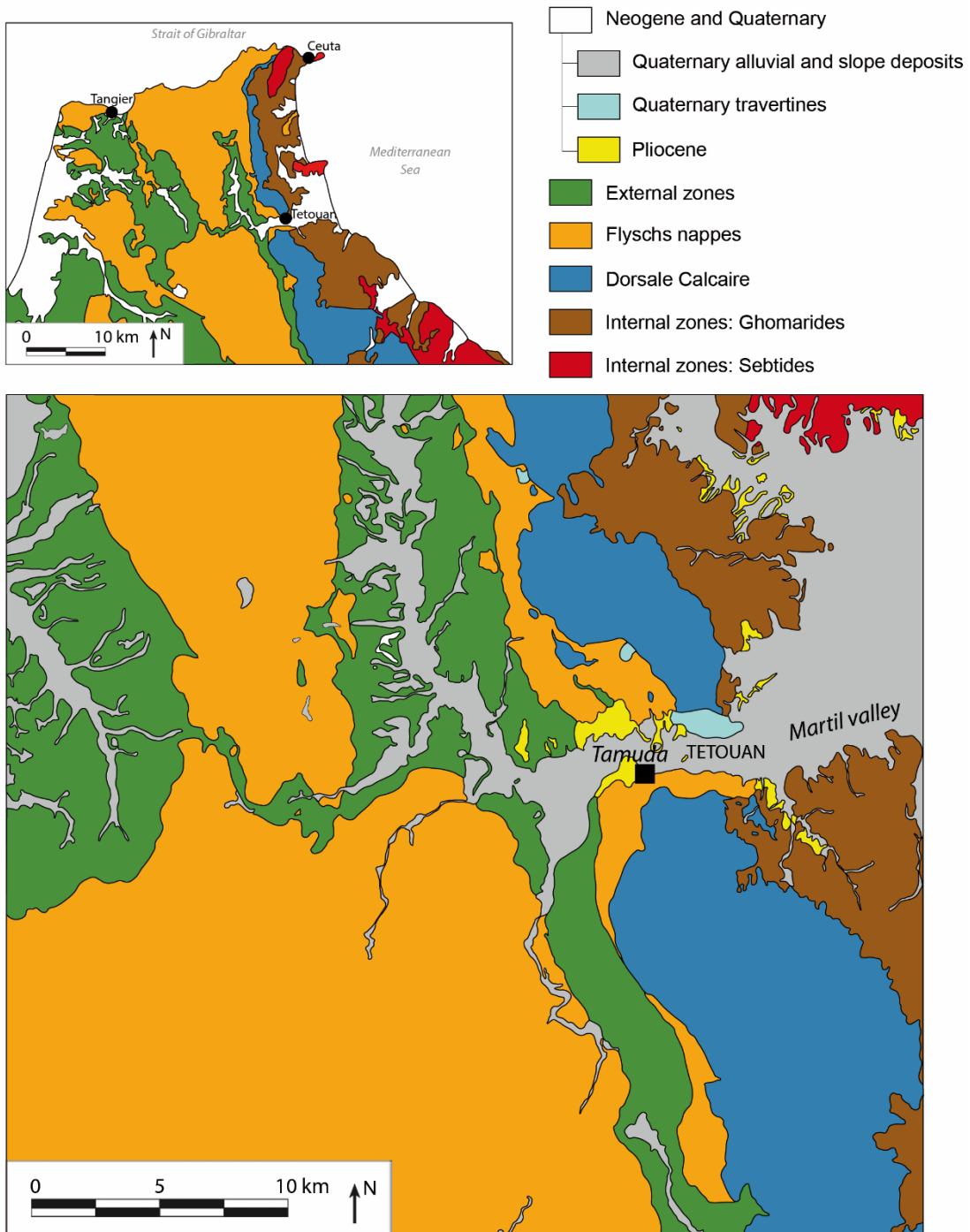


Figure 7. Geological map of the area of Tamuda, in Tetouan (based on El Kharim 2012)

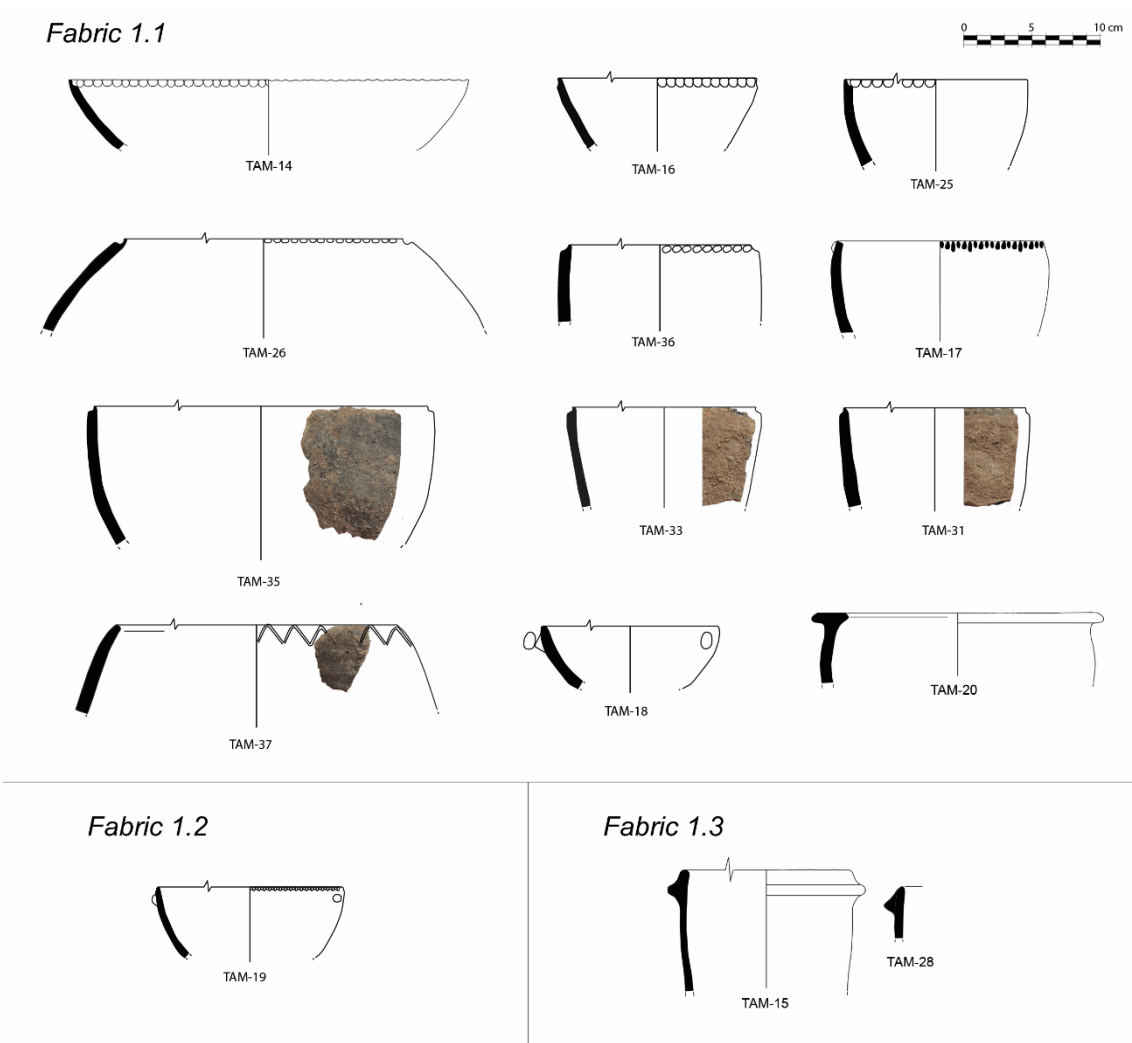


Figure 8. Illustrations of the pottery samples analyzed from Tamuda, showing the typological repertoire associated with Fabrics 1.1, 1.2, and 1.3

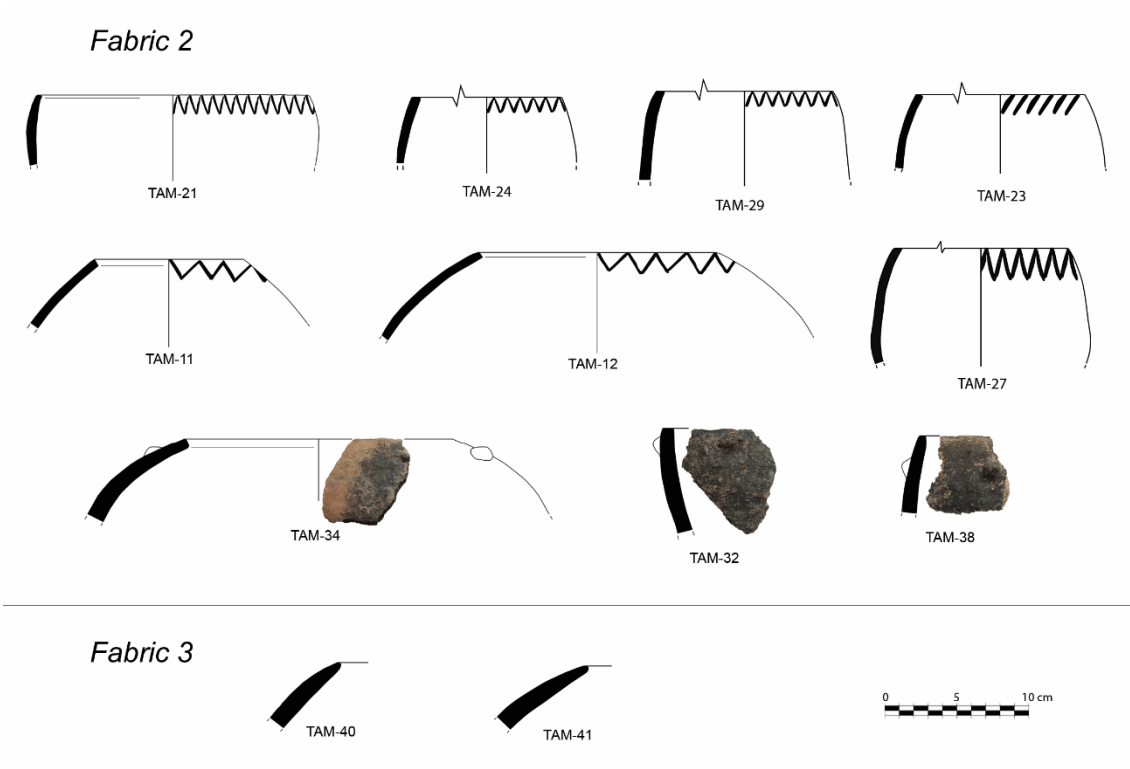


Figure 9. Illustrations of the pottery samples analyzed from Tamuda, showing the typological repertoire associated with Fabrics 2 and 3

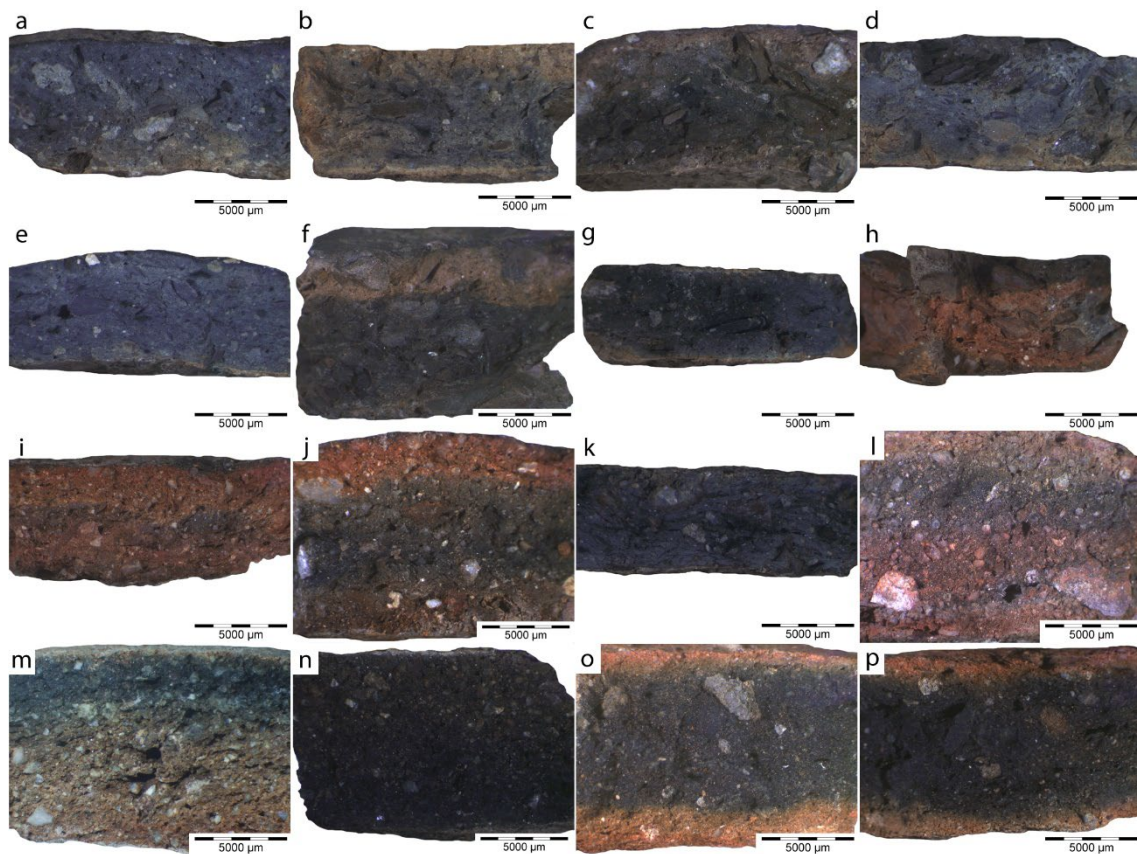


Figure 10. Photographs of fresh breaks (7.5x) of handmade or slow wheel-made pottery samples from Tamuda: a-f, Fabric 1.1 (a, TAM-16; b, TAM-25; c, TAM-26; d, TAM-33; e, TAM-36; f, TAM-37); g, Fabric 1.2 (TAM-19); h, Fabric 1.3 (TAM-28); i-n, Fabric 2 (TAM-13; j, TAM-22; k, TAM-24; l, TAM-30; m, TAM-34; n, TAM-38); o-p, Fabric 3 (o, TAM-40; p, TAM-41)

Table captions

Table 1. List of Roman handmade/slow wheel-made pottery samples analyzed from Tamuda, and applied techniques

Table 2. Summary of the results obtained from thin section petrographic analysis and XRD mineralogical analysis. Abbreviations: PPL, plane polarized light; XP, crossed polars; EFT, equivalent firing temperature

Table 3. Normalized elemental composition of the 16 ceramic samples that were analyzed by WD-XRF, organized by petrographic fabric. Concentrations of oxides are given in %, trace elements in ppm. Mean (m) and standard deviation (sd) values for each element are given in the case of Fabrics 1.1 and 2