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Production and distribution of Late Antique utilitarian wares in the micro-region of Vallès (Catalonia, Spain): a perspective from the rural hinterland of *Barcino*

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Abstract:

Cooking and common wares presumably produced regionally are frequent in archaeological context of Late Antique rural sites in northeastern Spain. A total of 142 of these wares from four settlements in the region of Vallès, in the surroundings of the ancient city of *Barcino*/Barcelona, were characterized through a combination of instrumental analytical techniques (OM, WD-XRF, and XRD), with the aim of investigating their provenance and production technology. The results confirm their regional provenance and suggest a local production of a part of the pottery assemblages, while also provide evidence of at least a secondary micro-regional trade during this period.

Keywords: Hispania, Catalonia, Late Antiquity, WD-XRF, XRD, petrography, cooking wares, provenance, ceramic technology

INTRODUCTION

The interest for the study of Late Antique cooking and common wares in northeastern Iberian Peninsula has notably increased in the last decades. These utilitarian vessels often account for a large proportion of the ceramic objects found in Late Antique archaeological contexts in this region, both in coastal urban sites (Macias 1999; Cela and Revilla 2004; Beltrán 2005; Macias and Cau 2012), and in rural settlements sometimes located in the hinterland of main ancient cities (e.g., Cau et al. 1997; Coll et al. 1997; López et al. 1997; Coll and Roig 2003). Their high frequency in archaeological contexts has encouraged researchers to examine issues regarding their production and distribution. The study of micro-regional production and distribution of utilitarian pottery contributes to a better understanding of Late Roman and early medieval procedures and networks (Wickham, 2005), with several studies focused in the studied area (Macias 2003; Riutort and Cau 2021; Travé et al., 2019, 2016). In particular, the occurrence of similar shapes in various sites, along with the strong similarities in macroscopic fabric observed for this class of ceramics on a regional level, have stressed the need to undertake an analytical approach on pottery assemblages from various sites to better explore these issues based on the petrographic and chemical characterization of the ceramic materials.

In the coastal area of present-day Catalonia, which in Late Roman times was the eastern part of *Hispania Tarraconensis*, such analytical studies have been conducted on cooking and common wares from urban contexts in Barcelona (Buxeda and Cau 2005) and Mataró (Buxeda and Cau 2004), related to the Late Roman cities of *Barcino* and *Iluro*, later renamed —during the Visighotic period— *Barcinona* and *Alarona*, respectively. These first studies included some imported wares in order to investigate their provenance and explore long-distance trade networks, but they focused mainly on presumably regional wares, providing a first insight into the diversity of utilitarian ceramics found in these urban sites.

As for Barcelona, in recent years a systematic program of archaeometric analysis of cooking and common wares has been investigating the patterns of pottery production, distribution and consumption in various rural sites of its hinterland, particularly in the current area of Vallès, Catalonia (Figure 1), between the 5th and 8th centuries AD. The research conducted so far, focused on utilitarian wares from case studies on specific sites (Riutort et al. 2017, 2018, 2020), has revealed a wide complexity of the ceramic assemblages. The characterization of the ceramics of each site was essential as a first stage of the research. However, the differentiation between ceramics produced locally at each site and those arriving from other sites in the same region has resulted problematic, and requires an in-depth study based on a wider micro-regional approach. For this reason, the aim of this paper is to carry out an integrated archaeometric analysis of cooking and common wares found and presumably produced in the rural settlements of the *ager* of *Barcino*, building upon the research carried out so far and integrating evidence from new analyses. The objective is to further explore the provenance and distribution, but also some technological features of the ceramics, based on the comparison among nearby sites as a basis for better investigating both local production and micro-regional trade of utilitarian wares during Late Antiquity in the region.

ARCHAEOLOGICAL SITES AND GEOLOGICAL BACKGROUND

Four sites were selected for this study: Ca l'Estrada (EST), in the current town of Canovelles (Fortó et al., 2006, 2011); Can Gambús (CG1), in present-day Sabadell (Roig and Coll 2006; Roig 2009); and Horts de Can Torras (HCT) and Plaça Major de Castellar del Vallès (PMCV), both in the current town of Castellar del Vallès, about 9 km north of CG1 (Coll and Roig 2006; Roig and Coll 2010) (Figure 1a). All of them are located in the area of Vallès, at a distance of 15-25 km north of Late Antique *Barcino*-*Barcinona*. The four sites were small rural settlements in Late Antiquity, each following the typical self-sufficient model of a Visigothic *vicus* or small village (Roig 2009, 2013), as suggested by their architectonical structures and the pottery assemblages. This type of settlement normally consisted of a dwelling area organized around huts, a storage area with silos, and a working area with several agricultural structures. Despite their similarities, the four sites were the result of two distinct settlement patterns. CG1 and PMCV show the evolution from a Roman *villa* whose structures were partly abandoned and partly reused for the construction of a new Visigothic *vicus* (Roig and Coll 2010), whereas HCT and EST were *ex novo* foundations with no previous Roman occupation. These transformations in settlement patterns started in the late 5th or 6th centuries AD and became established in the 8th century AD, not only in the Vallès (Roig, 2009) but also in the wider region of northeastern Iberia and other parts of former Roman *Hispania* (Chavarría 2007; Gurt and Navarro, 2005). So far, no pottery kilns were documented in these or other Late Antique sites of the Vallès region, although in PMCV there is a fifth-century AD kiln for firing building materials.

The area of Vallès has a heterogeneous geological background (ICGC 2005, 2006; Cirés and Berastegui 2011), with widespread formations of sedimentary, plutonic, and metamorphic rocks (Figure 1b). Three of these sites —CG1, HCT, and PMCV— lie in an area crossed by the Ripoll river in north-south direction, whereas EST is located farther than the other three sites, in the Congost valley. The four sites lie on Quaternary sediments —gravels, sands, silts, and clays— in the Catalan Coastal Depression. Two of them, HCT and PMCV, are situated at the foot of the Sant Llorenç del Munt mountain massif (Catalan Pre-Coastal Range), and therefore close to outcrops of Paleozoic granites/granodiorites and metamorphic rocks, and to a variety of sedimentary formations (Figure 1b). On the other hand, CG1, located further down the Ripoll river, and EST, in the Congost valley, are both very close to Neogene outcrops clays and sandstones; in any case, each of these rivers may transport other types of material from its upper course, including plutonic and metamorphic rocks from the upper Ripoll river, and plutonic rocks from the upper Congost river (Figure 1b). For these reasons, coarse-textured ceramics produced locally in these sites might contain sedimentary, plutonic, and/or metamorphic rock fragments and minerals in the case of HCT, PMCV, and CG1, and sedimentary and/or plutonic components in the case of EST.

SAMPLING AND ANALYTICAL METHODS

The archaeometric analysis was carried out on 142 ceramic samples from the four sites (see Table 2 in the additional supporting information). These included 55 samples from PMCV (contexts dated to 5th-7th centuries AD), 34 from CG1 (6th to mid-7th centuries AD), 30 from EST (5th-7th centuries AD), and 23 from HCT (from the latest phase of the site, dated between the 7th and mid-8th centuries AD). In summary, the complete sample covers a chronological span from the 5th century to the mid-8th century AD, including, therefore, the end of the Late Roman period and the entire Visigothic period in the area.

Most of the sampled potsherds belong to handmade or slow wheel-made cooking wares (n = 116) (Figure 1c), with clear predominance of cooking pots (n = 96) and lesser amounts of other forms, such as casseroles (n = 16), one-handle pots (n = 3), and lids (n = 1). Wheel-made or slow wheel-made common wares of presumably regional provenance were less frequent in the selected contexts (Figure 1c), and 22 of these ceramics were sampled for analysis, including mainly jars (n = 11) but also a few mortars (n = 6), basins (n = 3), bowls (n = 1), and dishes (n = 1). In addition, four handmade storage vessels or *dolia* were also included in the sample.

All these ceramics are generally undecorated, except for the rare occurrence of incised lines in a few pots. Based on the macroscopic examination of the ceramics, most cooking wares and a few common wares were fired in a reducing atmosphere during both firing and post-firing (cooling); conversely, most of the common wares, as well as a few cooking wares and all the *dolia*, were fired in reducing-oxidizing conditions (see Table 2 in the additional supporting information). Both types of firing procedures were observed in various forms of cooking and common wares, and they were found in approximately equal proportions in the four sites under study.

All the selected ceramic samples were analyzed using a combination of instrumental analytical techniques, including thin-section optical microscopy (OM), wavelength dispersive X-ray fluorescence (WD-XRF), and X-ray diffraction (XRD).

Petrographic-mineralogical analysis of the ceramics was carried out on thin sections using an Olympus BX41 optical polarizing microscope, working with magnification between ×20 and ×200. Ceramic fabrics were identified and grouped based on similarities in their inclusions, matrix, and microstructure (Whitbread, 1989, 1995; Quinn, 2013).

WD-XRF chemical analysis was performed using a PANalytical-Axios PW 4400/40 spectrometer. Fused beads were prepared for the determination of major and minor elements, while pressed powdered pellets were used to determine trace elements (for the analytical routine, see Buxeda et al. 2003). The elemental concentrations were quantified using a calibration line performed with 60 International Geological Standards. A total of 25 elements were measured: 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. The loss on ignition was determined by heating 0.3 g of dried specimen at 950°C for 3 hr.

The mineralogical composition of the ceramics was further examined by powder XRD through a PANalytical X'Pert PRO MPD alpha 1 diffractometer, working with the Cu Kα radiation (l = 1.5406 Å). Spectra were recorded between 5 and 80° 2θ, using a step-size of 0.026° 2θ 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.

The study was complemented with the petrographic analysis of four geological clay samples, potentially used for ceramic manufacture, that were collected from the vicinity of some of the sites: one (Clay-1) from Castellar del Vallès, near PMCV and HCT, and three (Clay-3, Clay-5, and Clay-6) from Sabadell, near CG1 (Figure 1b). Experimental briquettes were prepared for each clay sample and fired for 3 hr at two different temperatures, 850 °C and 950 °C, in controlled oxidizing conditions due to the technical characteristics of the kiln, . This was enough to obtain information about the viability of the clay samples and their geological composition. Thin sections for OM petrographic analysis were prepared from these briquettes and compared with the ceramic samples.

RESULTS

OM petrographic-mineralogical analysis

The petrographic analysis of thin sections by optical microscopy revealed that the majority (92%) of the samples could be assigned to two main fabric groups, 'coarse granitic' and 'coarse granitic and metamorphic', which are mainly distinguished by the type of inclusions that characterize their compositions (Figure 2). However, in both cases it was possible to differentiate a series of fabrics based on variations in other compositional and textural features within each group.

By far, the most common one is the ‘coarse granitic’ fabric group (Figure 2a-c), which includes 87 samples that account for 61% of the assemblage analyzed, and it is well represented in the four sites under study (Table 1). The best represented fabric in this group, CGF-1, found in 65 samples, is characterized by the dominant presence of inclusions derived from plutonic rocks, including mainly quartz, alkali feldspar, plagioclase (often with partial alteration into sericite), and biotite, as well as granitic rock fragments sometimes showing micrographic texture. This composition suggests derivation from alkali granite and granodiorite. Fragments of sedimentary rocks are also present in variable amounts, including quartz-sandstone and, more rarely, mudstone. The grain size distribution of inclusions is slightly bimodal, with an abundant moderately sorted coarse fraction —with mode 0.20-1.00 mm— and a finer fraction —mostly in the range 0.01-0.10 mm—,. All the samples are characterized by a non-calcareous matrix with colors ranging from brown to gray/black in PPL, in many cases with core-margin color differentiation. The matrix varies from optically inactive to optically active, even in a same sample; however, it should be borne in mind that the optical activity of the matrix may be less easily observed in samples of ceramics fired in reducing conditions (Quinn 2013).

Other seven fabrics in the ‘coarse granitic’ fabric group —CGF-2 to CGF-8— are much less common and may be interpreted as variants possibly related to the main fabric CGF-1 (see Table 1). Fabrics CGF-2, CGF-4, and CGF-5 were only found in samples of HCT, whereas fabrics CGF-6 to CGF-8 were exclusively observed in PMCV; the only exception was fabric CGF-3, identified in both sites (Table 1).

The other main group defined from the OM petrographic analysis is the ‘coarse granitic and metamorphic’ fabric group (Figure 2d-e), observed in 44 samples and therefore accounting for 31% of the assemblage. It is well represented in PMCV and CG1, but scarcely found in HCT, and very rare in EST (Table 1). Fabrics in this group are characterized by inclusions derived from plutonic rocks similar to those found in the ‘coarse granitic’ fabrics, but in this case containing also variable amounts of metamorphic rock fragments. The latter include mainly fragments of phyllite and quartzite, whereas other rock fragments likely derived from mica-schist and metagranite were also observed. Fragments of sedimentary rocks —sandstone and mudstone— are also common. The general characteristics of the matrix and grain size distribution of inclusions are like those observed in the ‘coarse granitic’ fabrics.

Most of the samples in this ‘coarse granitic and metamorphic’ fabric group share a similar fabric, CGMF-1 (Table 1), in which both granitic and metamorphic inclusions are dominant; the coarse fraction, moderately sorted, ranges predominantly from medium sand to very coarse sand grains. Other seven fabrics —CGMF-2 to CGMF-8—, less frequent in the assemblage, were differentiated based on the relative frequencies of granitic and metamorphic inclusions, and other compositional and textural features (Table 1).

In addition to the two main petrographic groups, a third group of ‘fine calcareous’ fabrics was identified (Figure 2f), which accounts for only 4% of the assemblage analyzed. It was observed in five samples from PMCV and CG1 (Table 1), while it is absent in HCT and EST. Fabrics in this group are characterized by a brown-orange matrix in PPL and a much finer texture than in previous fabrics. Inclusions are predominantly fine-grained, from silt to fine or very fine sand, whereas coarser grains are few to rare. They consist mainly of carbonate (micritic) inclusions, quartz, and micas (mostly biotite), while in the scarce coarse fraction it is possible to find occasional granitic inclusions, micritic lumps, sandstone fragments, and —only in samples from CG1— phyllite fragments. Even if slight textural variations were observed in this group —e.g., much higher frequency of fine inclusions in CG1007 than in the other four samples—, their similarities in composition and grain size distribution strongly differentiate them from the rest of the assemblage, suggesting the use of an untempered calcareous clay to manufacture the ceramics in this group.

Finally, six samples (4% of the total assemblage), coming from PMCV and CG1, were interpreted as petrographic singletons or loners, as they showed individual fabrics in thin section (Table 1; for further details on these singletons, see Riutort et al. 2017, 2020).

The clayey sediments analyzed from the Ripoll valley showed, in some cases, strong parallels with the two main petrographic fabric groups. Clay-1, from Castellar del Vallès, contained abundant coarse fragments of granite and so resulted highly similar to the 'coarse granitic' ceramic fabrics. On the other hand, samples Clay-3, Clay-5, and Clay-6, collected around Sabadell, contained both granitic and metamorphic rock fragments, ranging from a dominant metamorphic content (Clay-5) to a dominant granitic content (Clay-6). Therefore, these geological samples showed similarities with the 'coarse granitic and metamorphic' fabrics in terms of the composition of the inclusions —which were naturally present in the clayey sediments, compared to the ceramic fragments.

XRD mineralogical analysis

XRD analysis provided further information about the mineralogical composition of the ceramics. The examination of the mineral phases in each sample, including the primary phases and the eventual occurrence of firing phases and secondary (post-depositional) phases, allowed for an estimation of equivalent firing temperatures or EFT (Roberts 1963; Maggetti 1982; Cultrone et al. 2001; Cau 2003).

XRD results revealed strong similarities in mineralogical composition between samples of the 'coarse granitic' fabric group and the 'coarse granitic and metamorphic' fabric group, with a similar range of associations of mineral phases in both cases (see Table 3 in the additional supporting information). Most of the samples in these groups do not present clear firing phases, and therefore they should be associated with relatively low firing temperatures. The most frequent association comprises quartz, alkali feldspar, illite-muscovite, and plagioclase, suggesting an EFT not higher than 900/950 ºC; plagioclase in this case was interpreted as a primary phase, given the common presence of plagioclase inclusions observed in thin section. A few samples of both fabric groups contained also small peaks of calcite, suggesting an EFT lower than 800/850 ºC, if we assume a primary origin of this calcite (no significant evidence of secondary calcite was found for these samples under the optical microscope). Very occasionally, low reflections of hematite were also found in the XRD patterns of a few samples, which could be interpreted as either a primary phase or a firing phase under oxidizing conditions. The only clear firing phase was related to spinel peaks observed in a few samples of the two main fabric groups; in some of these cases, the additional absence of phyllosilicates points to an EFT higher than 950/1000 ºC (see Table 3 in the additional supporting information).

In summary, XRD results indicate that the ceramics of the two main fabric groups were fired, in most cases, at relatively low temperatures, with EFTs not higher than 900/950 ºC. In general, the ceramic samples from the four sites analyzed showed approximately the same variability in terms of mineral phase assemblage and EFTs (beyond the fact that the 'coarse granitic and metamorphic' fabric group is scarcely present in HCT and EST: Table 1). The only particularity is that the few higher fired samples —EFT 900-1000 ºC or above— in the 'coarse granitic' fabric group correspond in all cases to samples from PMCV, although high-fired samples from other sites —CG and HCT, in addition to PMCV— were found in the 'coarse granitic and metamorphic' fabric group (see Table 3 in the additional supporting information).

On the other hand, the five ceramic samples with 'fine calcareous' fabrics (Table 1) showed variability in their mineralogical composition and firing temperatures, from one sample with absence of clear firing phases and EFT below 800/850 ºC, to another sample with intense peaks of pyroxene and total decomposition of illite-muscovite, suggesting an EFT over 950/1000 ºC (see Table 3 in the additional supporting information). The rest of the samples in this group contain both illite-muscovite and firing phases —gehlenite, pyroxene, and possibly hematite— pointing to EFT in the range 850-950 ºC.

WD-XRF chemical analysis

A first examination of the chemical composition of the 142 ceramic samples analyzed through WD-XRF (see Table 4 in the additional supporting information) revealed some general trends. Almost all the samples are non-calcareous, characterized by low CaO concentrations (<5 wt%), with the only exception of five samples which showed CaO percentages between 6.0 and 10.7 wt% that correspond to the 'fine calcareous' fabrics (Table 1). All the sampling contain high percentages of SiO_2 (generally in the range 60-70 wt%), relatively high Al_2O_3 and K_2O (usually 15-20 wt% and 3-4 wt%, respectively), and variable amounts of Na_2O (0.4-2.6 wt%) and MgO (<2 wt% in most cases).

Calculation of the compositional variation matrix —CVM— (Aitchison 1986; Buxeda 1999) allowed for a more detailed examination of the chemical variability in this data set. This yielded a high total variation value (1.74), indicative of a polygenic assemblage. According to the CVM, the most variable elements in the data set are P_2O_5 ($\tau_{.i} = 11.30$), Na_2O ($\tau_{.i} = 6.79$), Cu ($\tau_{.i} = 6.56$), CaO ($\tau_{.i} = 5.83$), Ni ($\tau_{.i} = 5.71$), Cr ($\tau_{.i} = 4.00$), and Pb ($\tau_{.i} = 3.74$). Some of these elements —particularly P_2O_5, Cu, and Pb— were excluded from the multivariate statistical treatment as they might be associated with possible contamination problems. The high $\tau_{.i}$ for CaO is highly influenced by the presence of a few calcareous samples, while most of the assemblage showed CaO percentages below 3 wt% (Table 1). As for variations in Na_2O, these show a broad relation to the petrographic fabric groups previously identified, as 'coarse granitic' fabrics tend to present higher Na_2O percentages than 'coarse granitic and metamorphic' fabrics (Figure 3), likely associated with a higher relative frequency of plagioclase inclusions in the former.

To summarize the chemical results the dataset was further explored through cluster analysis (CA), after an additive log-ratio (alr) transformation of the concentrations (Aitchison 1986; Buxeda 1999), using Al_2O_3 as a divisor as it was the lowest variable element according to the CVM. The resulting cluster tree (Figure 4) revealed the presence of four main chemical groups (n > 5), V1 to V4, whose normalized composition is given in Table 5 in the additional supporting information. Group V1 comprises samples with calcareous composition, and it corresponds well with the ‘fine calcareous’ fabric group. Group V2 is a small and heterogeneous group of samples —related to various granitic and granitic-metamorphic fabrics— that show slightly higher CaO percentages (3-4 wt%) compared with the low calcareous ceramics in the assemblage in which CaO is usually lower than 3 wt%. Group V3, formed mainly by samples with ‘coarse granitic and metamorphic’ fabrics, and Group V4, predominantly related to ‘coarse granitic’ fabrics (Figure 4), are differentiated to each other by a higher content in Na_2O, Sr, Ba, and —in most cases— CaO in the latter (see Table 5 in the additional supporting information). In the main chemical group V4, two subgroups —V4a and V4b— seem to be well differentiated in the CA (Figure 4), as samples in V4a systematically show slightly lower concentrations of Ni and Cr than those in V4b (Table 5).

These relations can be visualized through a principal component analysis (PCA), performed on the same alr transformed subcomposition as the CA, but excluding the calcareous samples (Group V1) as well as a few chemical loners based on CA (Figure 5). Ni, Na_2O, Cr, and Sr dominate the first principal component, PC1, whereas PC2 is mostly influenced by CaO, Sr, Ni, and Ba. The biplot of PC1-PC2 illustrates well the differences between groups V2, V3, and V4 while, at the same time, shows the trend of higher content in Na_2O in the ‘coarse granitic’ fabrics than in the ‘coarse granitic and metamorphic’ fabrics (Figure 5).

The chemical groups defined from multivariate statistical treatment of the WD-XRF data are relatively homogeneous, as revealed by the total variation values obtained when CVM is calculated for each of them ($vt_{V1} = 0.41$; $vt_{V2} = 0.46$; $vt_{V3} = 0.46$; $vt_{V4} = 0.44$). Previous studies have shown that a *vt* value lower than 0.3 would represent a monogenic group of pottery (Buxeda and Kilikoglou 2003), although in some cases —especially in the case of handmade coarse-textured pottery— slightly higher *vt* values, up to 0.6/0.7, may also indicate geochemically related pottery or a broadly monogenic origin (Buxeda et al. 2001). This variability is even lower in the case of chemical subgroups V4a and V4b, with a *vt* value of 0.28 in both cases, suggesting a common origin for all the samples included in each subgroup.

DISCUSSION

Provenance

The petrographic-mineralogical composition of the ceramic fabrics in the four sites analyzed is, in almost all the cases, compatible with the hypothesis of a local provenance. In HCT, PMCV, and CG1, the series of granitic and granitic-metamorphic fabrics are compatible with the geological background of the stretch of the Ripoll valley where these three sites are located (Figure 1b). The analysis of clayey sediments in the surroundings of the sites supports this hypothesis, with the presence of naturally occurring granitic inclusions in all the clays, along with metamorphic inclusions in the clay samples from Sabadell (Clays 3, 5 and 6), near CG1. The absence of metamorphic inclusions in Clay-1 (likely related to fabric CGF-1) from Castellar del Vallès —close to HCT and PMCV— relates to the different geological formation where it was taken from, however it should be noted that similar clayey deposits to those in Sabadell, with both granitic and metamorphic contribution, can also be found in Castellar del Vallès (Figure 1b).

A few ceramic samples with 'fine calcareous' fabrics found only in PMCV and CG1, as well as a few samples with other distinct fabrics —petrographic singletons— from the same sites (Table 1), are also compatible with this geological background, as some of them can also contain occasional granitic and metamorphic inclusions. Even the singleton PMCV48, with accessory volcanic inclusions, is consistent with the occasional presence of localized volcanic rock deposits in the surroundings of PMCV (Cirés and Berastegui 2011; Riutort et al. 2020). The clay samples analyzed so far from the Ripoll valley did not show a content rich in carbonates, according to OM analysis, and thus cannot be associated with the 'fine calcareous' fabrics in the ceramics; if these latter were locally/regionally produced, the clay sources may be located closer to calcareous deposits in the same valley (Figure 1b), however further sampling and analyses of clays from this region is needed to identify the provenance and possible sources of raw materials for these calcareous wares.

On the other hand, almost all the ceramic samples analyzed from EST had 'coarse granitic' fabrics which are compatible with the geological formations that characterize the upper Congost river (Figure 1b). The only exception is sample EST013, whose granitic-metamorphic composition is not compatible with this area and therefore it might be a material arrived from another area, likely from one of the sites in the Ripoll valley, which indicates a probable micro-regional trade. This individual is close to chemical group V2, integrated by samples from Ripoll valley, mainly from PMCV.

The two main chemical groups defined from WD-XRF analysis were broadly associated with 'coarse granitic' fabrics (chemical group V4) and 'coarse granitic and metamorphic' fabrics (chemical group V3). However, in both chemical groups there are exceptions to this trend (i.e., some granitic fabrics in V3, and vice versa), which indicate that these two fabric groups cannot be clearly differentiated one from another in terms of chemical composition. If we consider the relatively low total variation values of these chemical groups, even when considered together ($vt_{(V3+V4)} = 0.60$), it is clear that both fabric groups share similarities in chemical composition and a broad geochemical relation. This supports the hypothesis that at least some of the granitic fabrics and some of the granitic-metamorphic fabrics may come from a same provenance area. Nevertheless, the occurrence of some granitic and granitic-metamorphic fabrics with other distinct chemical compositions —group V2 and several chemical loners— might indicate the occasional presence of ceramics either from other geochemical areas or from the same area but manufactured using slightly different sources of raw materials.

As concerns the 'coarse granitic' fabric group, it is interesting to note, on the one hand, that all the samples included in the chemical subgroup V4a come from the three sites in the Ripoll valley (HCT, PMCV, and CG1: Figure 4), so this subgroup likely represents a micro-regional paste compositional reference unit for pottery manufactured in Late Antiquity in this valley. Based on the existing evidence, it is not possible to know if the ceramics were produced in one of these sites and then traded to other sites, or if the three (or even more) sites were producing these wares by exploiting similar sources of raw materials in the same valley. The absence of samples with this chemical composition in EST, indicates that these wares with granitic fabrics from the Ripoll valley were not exported to this site of the Congost valley. On the other hand, most of the samples with granitic fabrics in subgroup V4b come from EST in the Congost valley (Figure 4), suggesting a possible local production. In any case, this chemical subgroup —with very low total variation— also includes some samples of granitic and granitic-metamorphic fabrics from sites in the Ripoll valley (Figure 4), which suggests that these samples were likely produced in this latter area —as metamorphic rocks are absent in the surroundings of EST— but using clay deposits very similar in geochemical composition to those found in the Congost valley. This is a plausible hypothesis since some geological formations outcrop in the two areas (Figure 1b).

In both the 'coarse granitic' and 'coarse granitic and metamorphic' petrographic groups, in addition to the main fabrics CGF-1 and CGMF-1, a variety of fewer common fabrics was identified, most of them —except for CGF-3, CGMF-2, and CGMF-5— found in only one of the four sites analyzed (Table 1). These various fabrics might represent local products from each site. One of these fabrics, CGF-2, showed a slightly distinctive chemical composition, but most of them cannot be differentiated geochemically from other fabrics in the same groups (Figure 4), reinforcing the hypothesis that they all come from the same provenance area, i.e., the Ripoll valley.

In summary, the combined petrographic and chemical evidence suggests that most of the cooking and common wares found in the four sites analyzed in this study could have been produced locally. In the case of EST, all the samples —except EST013 which was traded— were cooking wares with the same fabric (CGF-1) and very similar chemical compositions (subgroup V4b), probably due to the use of the same raw clayey deposits and paste recipes. Conversely, in the sites located in the Ripoll valley, the variety of fabrics and compositions identified, even within the same ceramic class (i.e., cooking wares, common wares, or storage wares), may be indicating that each site was exploiting various sources of raw materials in the surroundings, possibly as a result of various production units coexisting in each site.

Production technology

As concerns the manufacturing technology of the ceramics, a relation was observed between the class —and presumable function— of the pottery and the raw materials used, as well as, in most cases, the paste preparation.

All the cooking wares analyzed from the Vallès region were manufactured using non-calcareous clay pastes, and in almost all cases with coarse-textured fabrics containing granitic and, sometimes, metamorphic inclusions. The fact that in these cooking wares a variety of related fabrics was found with slightly variable chemical compositions would suggest the use of approximately similar clayey raw materials, likely associated with the same geological formation, but from different locations in the Ripoll and Congost valleys, presumably from the vicinity of the sites. This variability was independent of the type of cooking ware, since various forms of cooking pots and casseroles showed a similar range of fabrics and compositions.

Despite the variability associated with the exploitation of slightly distinct clay sources, it seems evident that similar paste recipes were used in the production of cooking wares. The analysis of clay samples from the Ripoll valley, containing coarse granitic and —in some samples— metamorphic inclusions like those found in the ceramic samples in terms of composition, sorting, and grain size distribution, suggests the use of unrefined (or poorly refined) raw clays rather than the intentional addition of temper during pottery manufacture. In addition, the cooking wares were usually fired in a reducing-reducing atmosphere at relatively low temperatures, generally below 900/950 ºC, with occasional exceptions.

In summary, the technological characteristics of cooking wares, regarding raw material selection and processing, paste preparation, and firing, were broadly the same in all the Late Antique sites analyzed of the Vallès region. The intended function of these wares —i.e., cooking with direct contact to fire— influenced these potters' choices, as low calcareous clay pastes fired at relatively low temperatures were suitable for improving heat conductivity and thermal shock resistance during cooking process (Picon 1995; Hein et al. 2008; Müller et al. 2014; Travé et al. 2019).

The results also showed that the few storage wares or *dolia* analyzed, coming from HCT and PMCV (see Table 2 in the additional supporting information), were similar to the cooking wares in terms of fabrics (three of them belong to CGF-1 and one to CGMF-1) and technical features. They were manufactured using low calcareous clay pastes with a similar range of coarse inclusions, and fired at temperatures not higher than 900/950 ºC. However, unlike the cooking wares, the *dolia* were fired in all cases under reducing-oxidizing conditions.

In the case of common wares, a higher diversity of technological choices was found. The 22 samples analyzed, found in the three sites of the Ripoll valley (HCT, PMCV, and CG1), revealed, in most cases (14 samples), a variety of 'coarse granitic' fabrics (CGF-1, CGF-3, CGF-5, and CGF-8) and 'coarse granitic and metamorphic' fabrics (CGMF-1, CGMF-3, CGMF-5, CGMF-6, and CGMF-7). Some of these (CGF-8, CGMF-3, and CGMF-6) were exclusively associated with common wares, while the other fabrics are like those found in cooking or storage wares. These coarse-textured granitic or granitic-metamorphic fabrics were manufactured using clay pastes with a low calcareous composition —as in almost all the cooking wares— or, in some cases, with a border calcareous composition (chemical group V2: Figure 4), with CaO 3-4%, revealing in this case the use of slightly different raw materials and/or paste recipes. They were usually fired at temperatures below 900/950 ºC, but —unlike the cooking wares— with predominance of reducing-oxidizing firing conditions. In addition, other common wares were related either to petrographic singletons (PMCV13, PMCV26, and CG1005) or to the 'fine calcareous' fabric group from CG1 and PMCV (n=5, see Table 1). This suggests the use of different clayey raw materials and paste recipes compared with other samples of the same forms —e.g., jars, mortars— and apparently intended for the same function. The use of calcareous clays for manufacturing common wares might have provided some technological advantages, such as the reduction of shrinkage time and a better thermal shock resistance during firing (Albero 2014). In any case, the results of this study show that this choice was made only in a few of the common wares produced in these sites of the Ripoll valley, whereas in most cases other raw materials and processing techniques were used, sometimes following the same choices as in the production of cooking or storage wares. The results also show no direct relation between these various potters' choices and the form of common ware, as different forms —jars, mortars, and basins— were each observed in a variety of fabrics and chemical compositions (Figure 4).

From a diachronic point of view, it is noteworthy that the ceramics from HCT, which all come from a slightly later context (7th to mid-8th centuries AD) than the ceramics from other sites in this study (PMCV, CG1, and EST, broadly dated to the 5th-7th centuries AD), showed a clear predominance of 'coarse granitic' fabrics, whereas the 'coarse granitic and metamorphic' fabrics were very rare (Table 1). The remarkable proximity of this site to PMCV, where both petrographic fabric groups were equally frequent, might be indicating a change in the raw clay deposits exploited for pottery production in this area towards the end of the Late Antique period, with a lower diversification of the clay pastes used and the resulting ceramic fabrics.

CONCLUSIONS

The comparative analysis of a large number of ceramics from four Late Antique sites (5th-8th centuries AD) in the region of Vallès, Catalonia, provided significant evidence of their production patterns and technological features. The obtained results strongly support the hypothesis of a regional provenance of these ceramics, following in most cases a similar range of technological choices. In the case of the three sites located in the Ripoll valley (PMCV, HCT, and CG1), the high inter-site similarities, resulting from their proximity to one another and from a similar geological background (which may have derived in the use of geochemically related raw clay deposits), makes it difficult to determine if the pottery assemblages were each produced locally or were mostly manufactured at one site and then distributed to the other sites through intra-valley trade. However, the evidence obtained —e.g., several fabrics that were found only in one of the sites— suggests that at least a part of the pottery assemblage from each site was likely produced locally. As for the site of EST in the Congost valley, the combined petrographic and chemical evidence pointed to a highly probable local production of most of the cooking ware assemblage. In any case, one of the samples analyzed from this site (EST013) was incompatible with the local geology and must have been obtained, most probably from the Ripoll valley area. This indicates that at least a very minor micro-regional trade took place among the sites of the Vallès region in this period.

The ceramic assemblages analyzed in this study must be interpreted in the framework of a transitional period that marked the end of Late Antiquity in northeastern Iberia. The rural settlement patterns established during the Visigothic period —after the collapse of the Late Roman Empire— were reflected also in transformations of the models of pottery production and consumption. The self-sufficient economy that characterized these settlements was directly associated with a decrease in the imports of utilitarian pottery. This process was also observed in the coastal cities (e.g. Barcelona and Tarragona), where cooking and common wares imported from other Mediterranean regions were gradually replaced by autochthonous products from the 5th and, especially, the 6th century AD (Cau et al. 1997; Coll and Roig 2003; Roig and Coll 2012; Macias and Cau 2012). Consumption of utilitarian wares manufactured regionally was clearly dominant during the entire Visigothic period in northeastern Iberia, a trend that persisted in the Early Medieval period (Travé et al., 2016). In this context, the analytical results obtained in the micro-region of Vallès support this interpretation and, moreover, suggest that the Late Antique rural sites analyzed produced cooking and common wares and, to a lesser extent, distributed them regionally.

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TABLE/FIGURE CAPTIONS

Fig. 1. (a) Location of the four Late Antique rural sites and clay samples analyzed in the Vallès region, northeastern Iberia. (b) Geological map of the Vallès region, with indication of the sites analyzed (based on ICGC 2005, 2006). (c) Representative illustrations of regional cooking and common wares from these sites.
Fig. 2. Photomicrographs of ceramic thin sections of the three petrographic fabric groups identified, taken under crossed polars (XP) at 40x: (a-c) Coarse granitic fabric group, samples HCT011, EST012, and PMCV36. (d-e) Coarse granitic and metamorphic fabric group, samples CG1017 and PMCV39. (f) Fine calcareous fabric group, sample GG1037.
Fig. 3. Binary diagram, using normalized data, of CaO vs Na_2O, for the 142 ceramic samples from the Vallès region, with indication of the petrographic fabric group for each sample.
Fig. 4. Dendrogram resulting from cluster analysis, using the centroid agglomerative method and the squared Euclidean distance, on 142 ceramic samples, based on the subcomposition Fe_2O_3, MnO, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2, Ba, Ce, Cr, Ga, Nb, Ni, Rb, Sr, Th, V, Y, Zn and Zr., using Al_2O_3 as divisor in the log-ratio transformation of the data. Chemical groups (V1 to V4) and subgroups, as well as the petrographic and typological data for each sample, are indicated.
Fig. 5. PCA based on the alr-transformed chemical data of 132 samples (excluding group V1 and loners), using Al_2O_3 as divisor. Plot of the first two principal components (PC1-PC2), which account for 42% and 14% of the total variance, respectively. Sampling site and petrographic data for each ceramic sample are given. Chemical groups (V2 to V4) derived from cluster analysis are indicated.

Table 1. Summary of the results obtained from the thin section petrographic analysis.
Table 2. List of ceramic samples analyzed, organized by sampling site, ceramic class/form, and firing atmosphere.
Table 3. Summary of the results of XRD mineralogical analysis, including estimation of equivalent firing temperatures (EFT). Abbreviations for minerals (based on Kretz 1983): Qtz, quartz; Kfs, K-feldspar; Pl, plagioclase; Ill-Ms, illite-muscovite; Cal, calcite; Hem, hematite; Spl, spinel; Tlc, talc; Ghl, gehlenite; Px, pyroxene. (+): very low intensity peaks.
Table 4. Elemental composition of the 142 ceramic samples analyzed through WD-XRF. Concentrations of oxides (and LOI) are given in %, trace elements in ppm.

Table 5. Mean normalized elemental composition (WD-XRF) of the chemical groups V1 to V4 —and the two subgroups V4a and V4b— defined from multivariate statistical analysis of the data. Mean (m) and standard deviation (sd) values are given for each element. Concentrations of major and minor oxides are in %, trace elements in ppm.