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A SINGULAR CERAMIC TYPE IN LATE IRON AGE NORTHWESTERN IBERIAN PENINSULA: AN ARCHAEOLOGICAL AND ANALYTICAL APPROACH

Alba Antía Rodríguez Nóvoa[1]*, Leandro Fantuzzi[2], Adolfo Fernández Fernández[3], Miguel A. Cau-Ontiveros[4]

[1]Contratada Margarita Salas, Universidade de Santiago, UrbNet-Aarhus University, Spain
[2]ERAAUB / IAUB, Universitat de Barcelona (UB), c/ Montalegre 6-8,
08001 Barcelona, Spain
[3]Contratado Ramón y Cajal. GEAAT-Universidade de Vigo, Spain
[4]ICREA, Passeig Lluís Companys 23, 08010, Barcelona, Spain; RYC2018-024131-I ERAAUB/IAUB, Universitat de Barcelona (UB), c/ Montalegre 6-8, 08001 Barcelona, Spain; Chercheur Associé, Aix Marseille Univ, CNRS, CCJ, Aix-en-Provence, France

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**Corresponding author: A. A. Rodríguez Nóvoa (albaantia.rodriguez.novoa@usc.es)*

ABSTRACT

This contribution offers a study of one of the most particular ceramic forms found in the material culture of the Iron Age of the north-western Iberian Peninsula: the cylindrical vessels. These objects, in their different formats, are typical of the middle and/or lower basin of the Miño River, found in contexts between the mid-1st century BC and mid-1st century AD. Throughout the text, we describe this type in depth and investigate the form from its possible origins (given its difference from the rest of the Iron Age forms), diffusion, functionality, and we try to provide a chronology as precise as possible. Traditional archaeological methodology is combined with archaeometry and ethnography. A total of 15 sherds from four archaeological sites of the Miño river middle basin were analyzed using a combination of techniques, including optical microscopy (OM) for the petrographic-mineralogical characterization of the materials, X-ray diffraction (XRD) for further details on the mineralogical composition, and wavelength dispersive X-ray fluorescence (WD-XRF) for the chemical characterization. This type of study allows us to better understand not only the material culture, but also the cultural and socioeconomic dynamics of the moment of transition between the Iron Age and the Roman Age.

KEYWORDS: pottery, late Iron Age, archaeometry, north-western Iberian Peninsula, petrography, WD-XRF, XRD

1. INTRODUCTION

Some of the most relevant sites for the study of the Iron Age in the northwest of the Iberian Peninsula are found in the lower-middle basin of the Miño river, in present-day Galicia, Spain (Fig. 1). Although the evidence for the earliest phases is scarce (González Ruibal, 2006: 328-348; Álvarez González, 2019: 752-768), the turn of the Era (1st century BC-1st century AD) has left some major hillforts or oppida which illustrate the transition between the Iron Age and the Roman period. As noted, the evidence available for the earliest Iron Age (10th/9th-6th centuries) is limited and unclear, and mostly comes from the excavation of the castro of Laias (Álvarez González and López González, 2000; Tereso et al., 2013). Beginning with the second Iron Age (6th-2nd centuries BC), the region presents some regularity in terms of settlement type, material culture and other cultural expressions (Rey Castiñeira 1991: 412-13, 2014, 289; González Ruibal, 2006: 466-500), as illustrated by castros such as Forca (Carballo Arceo, 1987), San Trocado (Fariña Busto and Xusto Rodríguez 1988) and Ourantes (López González, 2004). Coastal settlements began receiving imports from the southern Iberian Peninsula through the mediation of Cádiz merchants who reached the northwest, although the presence of these goods in the interior is very limited until the 1st century AD (Naveiro López, 1991; Fernández Fernández, 2014). The late 2nd and early 1st century BC witnessed the foundation of large walled settlements, over 2.5 hectares in size. These are arranged in different quarters or habitation units and betray some concern for urban organisation; these settlements appear to operate as central places for the territory that surrounds them (González Ruibal, 2006: 328-48; Prieto Martínez et al., 2017). Some of them remained occupied until well into the Roman period, as suggested by material finds (Ferro Couselo and Lourenzo Fernández, 1971: 1976; Fernández Fernández and Rodríguez Nóvoa, 2016; Rodríguez Nóvoa et al., 2020), while others were abandoned relatively early, probably towards the mid-1st century AD (De la Peña Santos, 1986; Rodríguez Cao et al., 1993). It is in these oppida that we have found the ceramic type that will be the focus of this work, the so-called cylindrical vessels.

The study of Iron Age ceramics in the northwestern part of the Iberian Peninsula has traditionally focused on the typology and decoration of the vessels (Rey Castiñeira, 1979, 1991, 2014; Calo Ramos, 1999; González Ruibal, 2007; Fernández Fernández, 2009; Rey Castiñeira et al., 2013; Seoane Novo, 2016, 2017), often using ethnoarcheological and experimental archaeology approaches focused on understanding the manufacturing process (Rodríguez Corral, 2008; Rey Castiñeira et al., 2013; Teira Brión et al., 2013). Only a few studies have to date incorporated an inorganic analytical characterization (Vázquez Varela and Guitián Fernández, 1981; Rey Castiñeira and Soto Arias, 2002), or the study of the content/use by organic residues analysis by gas chromatography/mass spectrometry (GC/MS) as it was the case of the so-called "Tipo Toralla" jars (Amado Rodríguez et al., 2015).

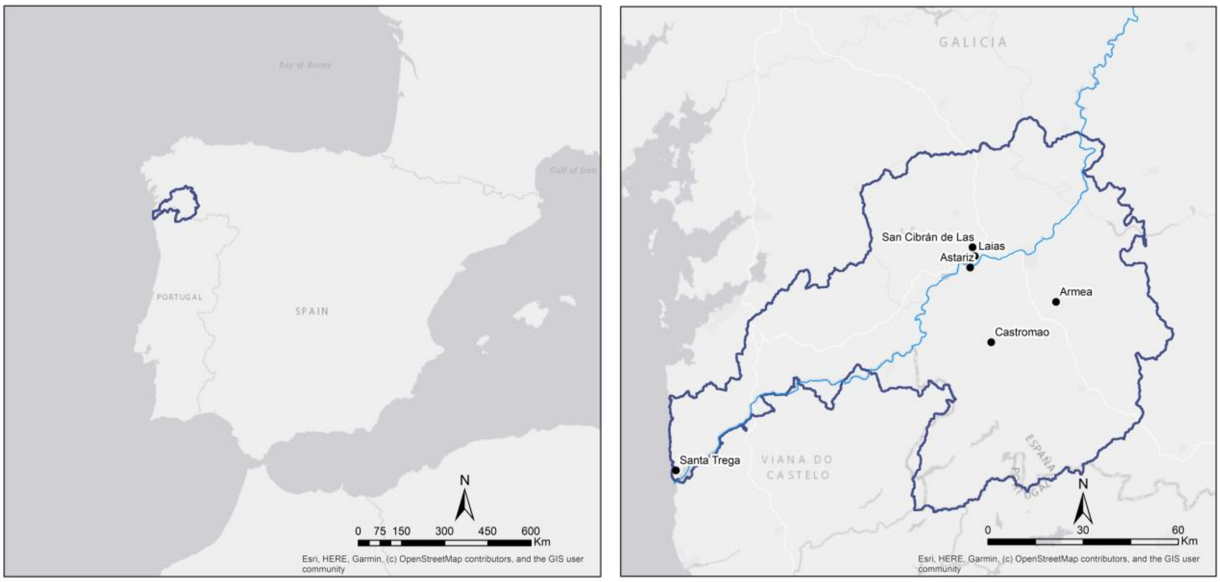

Figure 1. Location of the Miño valley area in northwestern Spain, and indication of the sites where ceramic cylindrical vessels have been documented (base map: ESRI; elaborated by the authors).

In the context of a recent study on the ceramics of the turn of the Era (1st century BC-1st century AD) in late Iron Age settlements of the middle Miño river basin, special focus has been given to an unusual form of the ceramic repertoire: the cylindrical vessels, also designated in the bibliography as 'San Cibrán vessels'. To shed some light about its production and distribution, an analytical characterization of cylindrical vessels from five important archaeological sites in the middle and lower valleys of the Miño River (Santa Trega, Laias, San Cibrán de Las, Castromao, and Armea) (Fig. 1), the main area of diffusion of this form, was carried out. The vessels under examination come from paradigmatic settlements for the final phases of the Iron Age and represent different settlement typologies. Santa Trega is a major oppidum situated at the mouth of the Miño River, fully exposed to commercial influences through the Atlantic route; the Late Republican and turn-of-the-era contexts have yielded abundant Mediterranean and southern Iberian ceramic imports (De la Peña Santos, 1987). Laias is situated in the centre of the area under study, a few kilometres from San Cibrán de Las –site from which the name of the ceramic type is derived – and presents a long chronology that runs from the Late Bronze Age to the early 1st century AD (Rodríguez Nóvoa, 2020). San Cibrán de Las is a large oppidum-type settlement that peaked around the turn of the era, and probably was the head settlement in the middle Miño basin. Finally, Armea and Castromao are found in secondary valleys in the basin, near Las and Laias but under a different territorial-political entity in the pre-Roman period. Castromao was continuously occupied from the late Iron Age to the 2nd century AD, while Armea was founded in the early 1st century AD as a Roman ex novo settlement; the town expanded during the Flavian period and remained occupied until the 3rd century (Rodríguez Nóvoa et al., 2020).

This works presents the first wide archaeometric and archaeological study for a ceramic form from the turn of the Era, carried out with the aim of unveiling the origin and fabrication site of this singular type. It is the first time that a study of this characteristics is performed in the Northwestern of the Iberian Peninsula for the Iron Age or turn of Era pottery, and opens a new path to study these objects.

2. THE CYLINDRICAL VESSELS IN NORTH-WESTERN IBERIA

Cylindrical vessels are a singular form in the Iron Age ceramic repertoire (López Cuevillas, 1968; Rey Castiñeira, 1979, 1991; Pérez Outeiriño, 1987). It is a form with a cylindrical morphology, with straight walls and straight or slightly open rims (Fig. 2a). Examples with or without handles have been found. Handles that relate to this shape are typically vertical and have a cylindrical section, although fragments with ribbon handles and side flanges can also be found. Although smooth glasses may appear, it is usually a piece decorated with incised lines or stamps arranged in horizontal bands. The shape and decoration of this type is reminiscent of the wooden cauldrons or jugs, which could place as the origin of these cylindrical vessels, since, for the moment, we have not found previous experiments made in ceramics with this morphology. Another hypothesis would be that they were an imitation of an exogenous form. Imitations of crater handles that are incorporated into traditional Iron Age forms have previously been documented (Amado et al., 2015, 107–108; Rey Castiñeira, 2020, 437–440). The cylindrical shape of the vessels resembles the Iberian *kalathoi*, which have been widely documented in Galician deposits (Naveiro López, 1991, 26), although not in the middle Miño valley, which would be the central manufacturing area for the cylindrical vessels.

The sizes are very varied, oscillating the diameter of the rim between 5 and 35 cm and the height of the vessel between 5 and 25 cm; there is a clear correlation between the height and diameter of the rim in these vessels. Few complete specimens have been recovered, but considering those that can be measured, we can distinguish three large groups according to the volume of the vessel (Fig. 2a): small (from 100 cm to 3,500 cm^3), medium (between 10,000 and 15,000 cm^3) and large (about 20,000 cm^3). These size differences would respond to different functions, although we believe they would mostly be related to their use to consume or contain liquids. The inner resin presented by some specimens would give them some waterproofing (Fig. 2b). Some vessels with perforations at the bottom may also have functioned as molds for cheese making.

Traditionally these forms are dated to the Iron Age, especially in the change of Era. However, from the ceramic contexts studied by us in San Cibrán de Las, Laias, Santa Trega or Armea, we propose a chronology of production that would go from the second half of the 1st century BCE to the mid-1st century AD, with a possible survival in a residual way still in the late 1st century AD contexts. However, the flourishing period of the form should be limited in the change of Era since the cases of cylindrical vessels associated with south Gaulish *terra sigillata* in mid-1st century AD are just a few. The occurrence of cylindrical vessels in contexts with presence of Hispanic *terra sigillata*, as is the case in contexts of destruction and abandonment of San Cibrán de Las or Armea, should be understood as a phenomenon of residuality. In general, cylindrical vessels appear in contexts associated with Campanian black-glazed and its Hispanic imitations, Italian *terra sigillata* and regional imitations, South Gaulish and and amphorae from Italy (Dressel 1) and Baetica (ovoid types, Late Punic, Haltern 70, Dressel 7-11, and Urceus Type).

Figure 2. (a) Different types of cylindrical vessels based on their shape and volume. (b) A cylindrical vessel with remains of resin on its inner wall.

The current fundamental problem around cylindrical vessels lies in their provenance and distribution. Little is known about Iron Age ceramic production in the region, since, so far, no structure has been found that can be clearly identified as a ceramic kiln. Due to the abundance of this type of vessels in San Cibrán de Las and Astariz hillfort, in the middle basin of the Miño River, and the scarcity in other sites, we pose the question of their provenance, with two initial hypotheses: a) that the vessels were manufactured in San Cibrán de Las and/or Astariz Hillfort and then distributed to other settlements in the region; b) that it was really the idea that circulated through the northern territory of present-day Galicia through the Miño river, but the vessels were manufactured independently in each of the *castros*. In any case, it should be noted that this form was very rarely manufactured outside the core of the Miño river valley.

3. MATERIALS AND METHODS

To try to elucidate these starting hypotheses, 15 cylindrical vessels recovered in San Cibrán de Las (n=8), Castromao (n=3), Santa Trega (n=2), Armea (n=1), and Laias (n=1) were analyzed (Table 1; Fig. 3). The availability of vessels from San Cibrán de Las and the starting hypothesis that this was the producing center induced a larger sampling at this site. The sample includes sherds from most deposits where this vessel has been identified so far. Individuals with different sizes, decorations and macroscopic characteristics were chosen. In fact, the macroscopic examination of the 15 ceramic samples revealed a wide diversity of macro-fabrics (Fig. 4).

All samples were analyzed using a combination of analytical techniques. Petrographic-mineralogical characterization has been carried out through optical microscopy (OM). Mineralogical characterization has been completed by X-ray diffraction (XRD), and chemical characterization has been performed by wavelength dispersive X-ray fluorescence (WD-XRF). A similar combination of techniques has been proved as an appropiated methodological approach for the provenance and technological study of archaeological ceramics, as it has been demonstrated by numerous studies worldwide for ceramics from many different chronological periods (e.g. Maniatis et al. 1984; Day et al. 2011; Gauss and Kiriatzi 2011; Abdel Rahim 2016; Javanshah 2018; Cau et al. 2019).

For the petrographic-mineralogical study using OM, thin sections with a thickness of 30μm were prepared for each ceramic sample. These were analyzed using an Olympus BX41 microscope, working with a magnification range from x20 to x200. The petrographic study of the fabrics was made following the system proposed by Whitbread (1989, 1995) and Quinn (2013). Grain sizes for inclusions in petrographic descriptions are based on the American Geophysical Union system (Udden-Wentworth scale).

The mineralogical composition by XRD was obtained using a PANalytical X'Pert PRO MPD alpha 1 diffractometer, equipped with a graphite monochromator in the diffracted beam at 1.2 kW, 40 kV, 30 mA, and working with Cu-Kα radiation (λ = 1.5406 Å). A part of the sample in a powdered and homogenized state was used for this analysis, as in chemical analysis. Measurements were taken from 4 to 70°2θ with a step-size of 0.05°2θ and a steptime of 3 s. The evaluation of the crystalline phases present was carried out using the PANalytical's HighScore Plus software, which includes the Joint Committee of Powder Diffraction Standards (JCPDS) database.

Figure 3. Fifteen cylindrical vessels (M01 to M15) selected for archaeometric analysis

Table 1. List of the analyzed samples, with information on their archaeological context

Sample	Inventory number	Site	Site chronology
M01	CE005232-23	San Cibrán de Las	Pre-Roman hillfort
M02	CE005232-20	San Cibrán de Las	Pre-Roman hillfort
M03	CE005247-54	San Cibrán de Las	Pre-Roman hillfort
M04	CE005247-61	San Cibrán de Las	Pre-Roman hillfort
M05	DX0044-157	San Cibrán de Las	Pre-Roman hillfort
M06	CE005232-98	San Cibrán de Las	Pre-Roman hillfort
M07	DX0403-13	Castromao	Pre-Roman and Roman hillfort
M08	CE004174/93	Castromao	Pre-Roman and Roman hillfort
M09	DX0403-8	Castromao	Pre-Roman and Roman hillfort
M10	CE005219-42	San Cibrán de Las	Pre-Roman hillfort
M11	Lai.C1.97.33.21	Laias	Pre-Roman hillfort
M12	Las.19D.03.3.2	San Cibrán de Las	Pre-Roman hillfort
M13	ST 2023	Santa Trega	Pre-Roman hillfort
M14	ST 1183	Santa Trega	Pre-Roman hillfort
M15	CC16-1565	Armea	Early Roman City

For chemical analysis by WD-XRF, specimens weighing at least 10 g were obtained from each of the sampled individuals. After detaching their surface layers, they were powdered and homogenized in a tungsten carbide mill. The samples, from the powder obtained, and after drying on a stove at 105 ºC for 12 hours, underwent different types of preparation. On the one hand, for measuring major elements, alkaline fusion beads were made with lithium tetraborate (dilution 1/20), with the use of an induction furnace. On the other hand, for measuring trace elements, powdered pellets were prepared from 5 g of specimen mixed with an Elvacite agglutinating agent, placed over boric acid in an aluminum capsule, and pressed for 60 s at 200 kN using a Herzog press. Quantification was performed through a Panalytical-Axios PW 4400/40 spectrometer with Rh excitation source using a calibration line configured with 60 patterns (International Geological Standards) (Hein et al., 2002). The following elements were thus determined: Fe_2O_3 (as Total Fe), Al_2O_3, MnO, P_2O_5, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2, Ba, Rb, Mo, Th, Nb, Pb, Zr, Y, Sr, Sn, Ce, Co, Ga, V, Zn, W, Cu, Ni, and Cr. It should be noted that, of these 29 elements, Mo and Sn were excluded due to low concentrations and analytical imprecisions, while Co and W were not considered due to possible contamination during sample preparation with the tungsten carbide mill. The chemical data obtained were examined through multivariate statistical methods, applying the transformation into additive log-ratios (*alr*) (Aitchison 1986, 1992; Buxeda 1999). Loss on ignition (LOI) was also calculated by firing 0.3 g of dried specimens at 950 °C for 3 h.

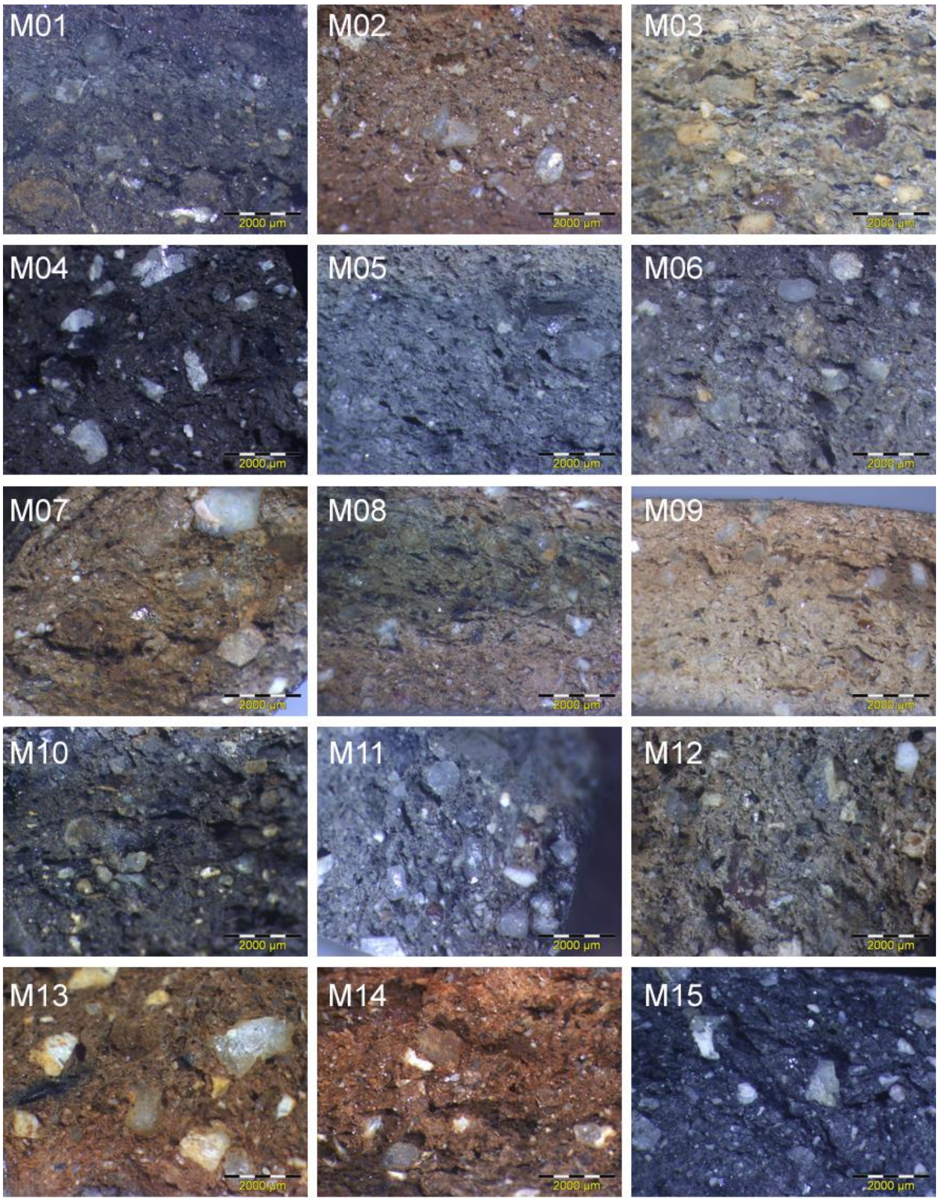

Figure 4. Photographs of fresh breaks (×15) of the 15 ceramic samples analyzed in this study.

4. RESULTS

4.1 *Thin-section petrographic analysis*

Thin-section OM analysis allowed the differentiation of a variety of fabrics (Fig. 5, Table 2), although all of them can be grouped within the same general petrographic group (Granitic Petrographic Group), based on the predominance of granitoid rock fragments and derived minerals in their inclusions.

In general terms, the fabrics in this group are characterized by a coarse texture, with inclusions (usually 25-35%) showing a bimodal grain size distribution, where a coarse fraction (>0.10 mm) can be differentiated from a fine fraction (0.10-0.01 mm), both being abundant. The coarse fraction is poorly to moderately sorted and composed of fine to very coarse sand, while granules (>2 mm) are very rarely observed. It is mainly composed of angular-subangular quartz (both monocrystalline and polycrystalline), micas (muscovite and/or biotite), alkali feldspar, and —in some cases— plagioclase, in addition to some plutonic rock fragments composed of these minerals and derived from a granitic source. A contribution of metamorphic rocks is usually observed, including rock fragments likely derived from quartzite and, in some cases, metagranite, phyllite or schist. Other accessory components of the coarse fraction may include chert, quartz sandstone, and argillaceous rock fragments. The fine fraction (0.10-0.01 mm) generally comprises dominant quartz and micas, along with less frequent iron oxides/opaques, alkali feldspar and, less frequently, plagioclase; other inclusions, like chert, tourmaline, epidote, and zircon, can be found as accessory components. Porosity in these fabrics ranges from 5% to 10% and consists of meso-sized vughs and vesicles and rare macro-vughs, while common elongated voids can be found in some samples. The color of the clay matrix under plane polarized light (PPL) is usually yellowish or brown, sometimes with a darkened core; no evidence for clay mixing has been observed in the analyzed samples. In all the samples the matrix displays optical activity under crossed polars (XP), which suggests relatively low firing temperatures.

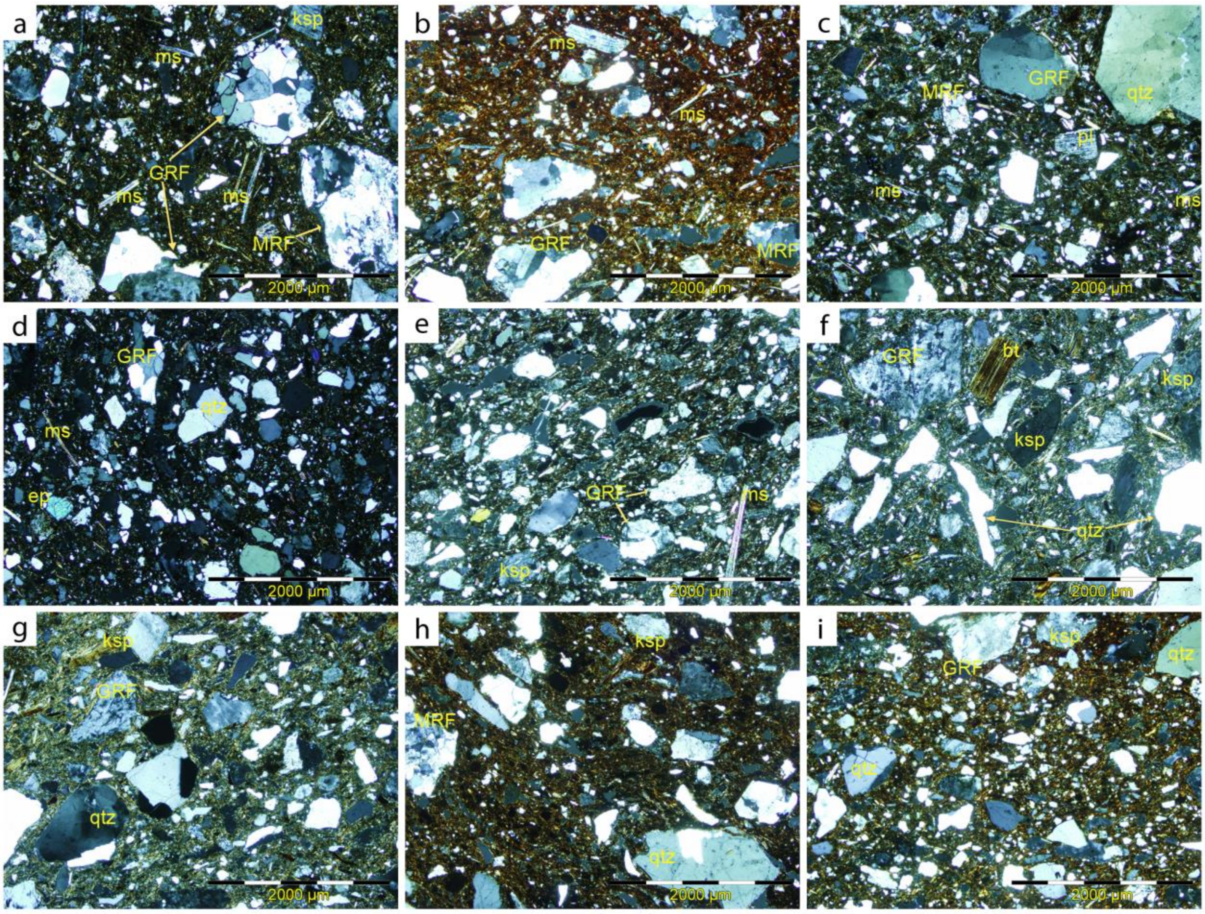

Figure 5. Photomicrographs of ceramic thin sections of the nine petrographic fabrics identified within the Granitic Petrographic Group, taken under crossed polars (XP) at 40x: (a) fabric CV-1, sample M10; (b) fabric CV-2, sample M02; (c) fabric CV-3, sample M07; (d) fabric CV-4, sample M05; (e) fabric CV-5, sample M15; (f) fabric CV-6, sample M12; (g) fabric CV-7, sample M11; (h) fabric CV-8, sample M04; (i) fabric CV-9, sample M13. Abbreviations for inclusions: qtz, quartz; ksp, alkali feldspar; pl, plagioclase; ms, muscovite; bt, biotite; ep, epidote; GRF, granitic rock fragment; MRF, metamorphic rock fragment

Table 2. Summary of the results obtained by the thin-section petrographic analysis

Petrographic fabric	Main distinctive characteristics	Samples	Site/s of the samples
Granitic Petro-Group	*Quartz (monocrystalline and polycrystalline), micas, alkali feldspar, granitoid rock fragments*	*All*	*All*
Fabric CV-1	Very rich in muscovite, metamorphic contribution	M01, M06, M10	San Cibrán de Las
Fabric CV-2	Very rich in muscovite, metamorphic contribution, iron-rich matrix	M02	San Cibrán de Las
Fabric CV-3	Very rich in muscovite, subordinate metamorphic contribution	M07, M08, M09	Castromao
Fabric CV-4	Very rich in muscovite, accessory metamorphic contribution, common heavy minerals	M05	San Cibrán de Las
Fabric CV-5	Very rich in muscovite, no clear metamorphic contribution	M15	Armea
Fabric CV-6	Very rich in biotite, accessory metamorphic contribution	M03, M12	San Cibrán de Las
Fabric CV-7	Moderate micaceous content (more biotite than muscovite), no clear metamorphic contribution	M11	Laias
Fabric CV-8	Few micas, accessory metamorphic contribution, less abundant fine fraction	M04, M14	San Cibrán de Las, Santa Trega
Fabric CV-9	Few micas, accessory metamorphic contribution, very abundant fine fraction	M13	Santa Trega

Despite these general characteristics, a significant variability was found within the Granitic Petrographic Group in terms of the relative frequencies of micas (and the relative abundance of biotite or muscovite), metamorphic rocks, and other components (e.g., plagioclase), as well as in textural parameters. Variations were also observed in the base-clays used. Based on these criteria, up to nine petrographic fabrics can be defined (CV-1 to CV-9: Table 2; Fig. 5). It is important to notice that the majority of these fabrics was identified only in one site: fabrics CV-1, CV-2, CV-4, and CV-6 were related exclusively to samples from San Cibrán de Las, while fabric CV-3 was found only in Castromao, fabric CV-5 in Armea, fabric CV-7 in Laias, and fabric CV-9 in Santa Trega. Only fabric CV-8 was related to samples from two different sites, San Cibrán de Las and Santa Trega (Table 2).

Five of these nine fabrics, CV-1 to CV-5 (Fig. 5a-e), were characterized by a very rich content in muscovite; biotite is also present in these fabrics but in minor amounts (it is however more common in CV-3 than in the others). CV-1 and CV-2 had common metamorphic rock fragments (mostly quartzite and metagranite), although CV-2 is differentiated by a more ferruginous clay matrix, with a red color (except in the core, which is darkened due to irregular firing conditions) instead of the yellowish or brown color observed in CV-1 and in other fabrics of the group. In other muscovite-rich fabrics, metamorphic rock fragments are less common (CV-3), accessory (CV-4), or absent (CV-5). Fabric CV-4 is also distinguished by its clearly higher content in heavy minerals, particularly tourmaline and epidote. Plagioclase inclusions —both as individual crystals or as part of granitoid rock fragments— are commonly observed in CV-3, CV-4, and CV-5, and are scarcer in CV-2, while in CV-1 they can be either common (sample M06) or rare (samples M01 and M10).

Another fabric, CV-6 (Fig. 5f), is very rich in biotite, along with common muscovite inclusions; very few plagioclase and rare metamorphic rock fragments are observed in this fabric. In fabric CV-7 (Fig. 5g), micas —both biotite and muscovite— are common but less abundant than in fabrics CV-1 to CV-6, and plagioclase inclusions are common; no fragments of metamorphic rocks were observed in this fabric.

Finally, there are two fabrics, CV-8 and CV-9 (Fig. 5h-i), with relatively few micas (more biotite than muscovite) and plagioclase, and accessory metamorphic rock fragments. The main difference between them is the higher frequency of fine quartz inclusions (<0.10 mm) in CV-9, what may suggest the use of distinct raw clayey sediments in each case.

4.2 XRD mineralogical analysis

The results of XRD analysis revealed clear similarities in the mineralogical composition of the 15 samples analyzed (Fig. 6). All of them showed the presence of primary crystalline phases and the absence of firing phases. The crystalline phases identified were quartz, phyllosilicates (illite-muscovite), alkali feldspar and, in almost all cases, plagioclase. Only in two samples, M02 and M14, low-intense peaks of hematite were observed (Fig. 6b, e), coinciding with the observation of a red-colored oxidized matrix in these samples to the naked eye (Fig. 4) and —particularly for M02— in thin section. In the remaining samples, diffractograms tend to be rather similar, the main difference being the relative intensity of plagioclase peaks. This phase, which should be considered primary in these cases, is generally well-developed, achieving maximum development in the M15 specimen (Fig. 6d), while it is only absent in M14 (Fig. 6e).

Overall, the crystalline phases observed by XRD are compatible with the results of the petrographic analysis, with the dominant presence of mineral inclusions derived from a granitic source (quartz, micas, and feldspars). XRD also confirms that all the samples were fired at relatively low firing temperatures, as suggested also by the optical activity of the clay matrix in thin section. Considering that these are samples of non-calcareous composition, the absence of firing phases like maghemite or hematite suggests that the Equivalent Firing Temperature (EFT) should be below 750 ºC (Maritan, 2004; Travé et al., 2019) for all the analyzed samples, with the possible exception of M02 and M14 providing that the low peaks of hematite in these samples were a firing phase under an oxidizing atmosphere.

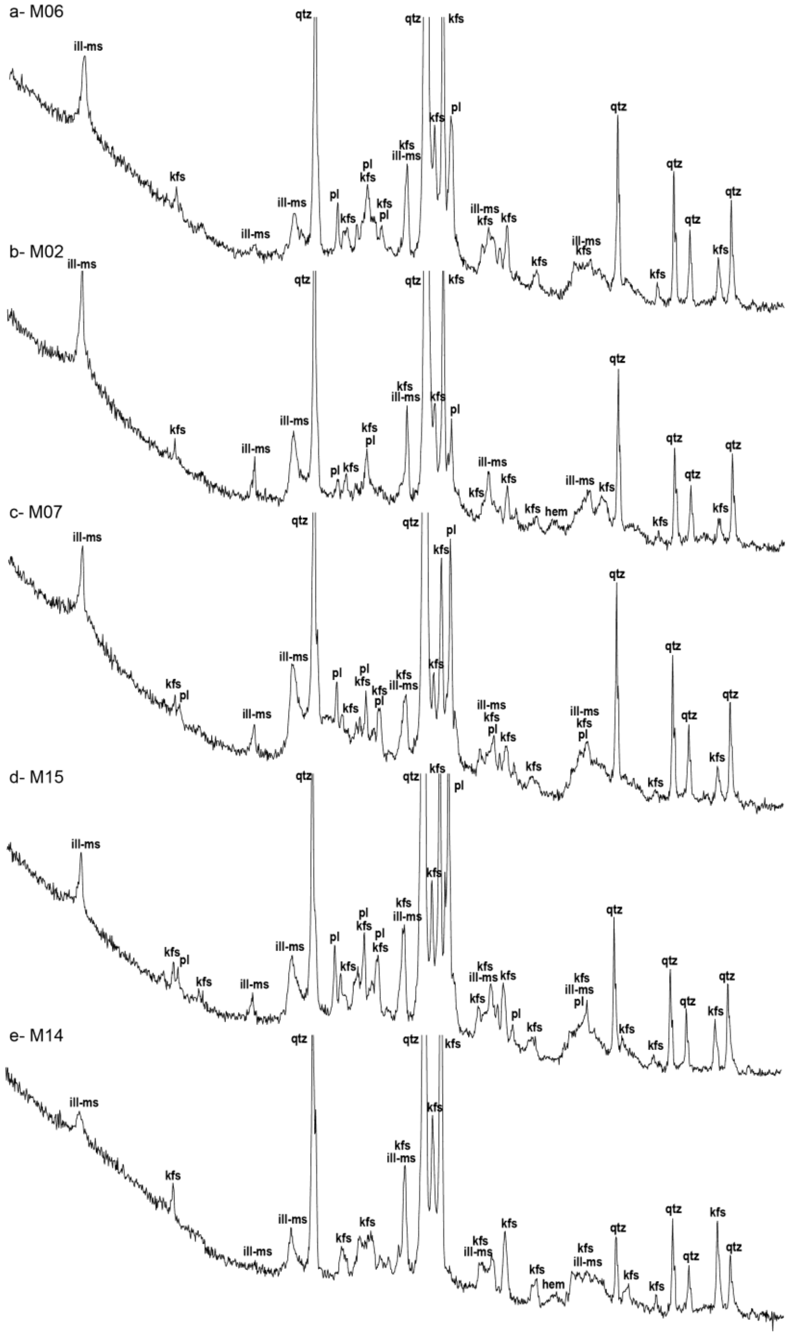

Figure 6. XRD spectra for some of the ceramic samples analyzed. Abbreviations for minerals (based on Kretz 1983): qtz, quartz; pl, plagioclase; kfs, alkali feldspar; hem, hematite; ill-ms, illite-muscovite.

4.3 WD-XRF chemical analysis

The chemical composition of the 15 individuals analyzed through WD-XRF is given in Table 3. A first examination of these data reveals, as a general characteristic, the presence of high percentages of Al_2O_3, K_2O, and SiO_2, as well as very low percentages of CaO and MgO. This composition shows the use of non-calcareous raw materials and can be related to the abundant presence of quartz, micas, and alkali feldspar observed through OM and XRD analyses. There seems to be greater variability, on the other hand, in the concentration of other elements, in particular Na_2O, Fe_2O_3, TiO_2, and P_2O_5 (Table 3).

One way to identify compositional variability in a dataset is by calculating the Compositional Variation Matrix (MVC) (Aitchison, 1986, 1992; Buxeda, 1999; Buxeda and Kilikoglou, 2003). This matrix includes information on both the total variation of the dataset (vt) and the variability introduced by each chemical element ($\tau_{.i}$). The total variation according to this MVC is very high (vt= 4.10), indicating the polygenic character of the dataset. This would demonstrate the existence of several products from different sites. The elements that introduce most of the variation in the data are Cr ($\tau_{.i}$= 24.58) and P_2O_5 ($\tau_{.i}$= 17.10), whose variations are easy to understand when observing the chemical data (Table 3), as Cr ranges between 6 and 144 ppm in the dataset, while P_2O_5 ranges between 0.23% and 2.36%. There are two samples, M11 and M15, with very high P_2O_5 (>2%), although they do not show any particularity in thin section nor in XRD that allows us to explain these percentages. It should be noted that P_2O_5 is susceptible to be affected by alteration phenomena and/or post-depositional contamination, so this variation should be taken with caution. Other elements that, according to MVC, introduce more than 50% of the variability in the dataset are Cu ($\tau_{.i}$= 13.22), Ni ($\tau_{.i}$= 10.96), Na_2O ($\tau_{.i}$= 10.27), Y ($\tau_{.i}$= 9.32), Sr ($\tau_{.i}$= 8.96), and CaO ($\tau_{.i}$= 8.61).

The WD-XRF elemental data were further explored through cluster analysis (CA), after an *alr* transformation of the concentrations, using Al_2O_3 as a divisor as it was the lowest variable element according to the CVM; the elements P_2O_5 and Pb were excluded to avoid problems arising from possible post-depositional alterations and/or contaminations. The resulting cluster tree (Fig. 7a) showed the division of the set into two main clusters, A and B, mainly based on the presence of higher concentrations of TiO_2, MgO, and Cr in cluster A than in cluster B. In the case of cluster A, these concentrations are even higher in some of the samples (M04, M08, and M09) than in others (M02 and M10), resulting in two separate subclusters. In cluster B, two samples (M11 and M15) differ from the others mainly due to the presence of higher levels of Sr and Zn (Table 3); also P_2O_5, not included in the cluster analysis, is very high in these two samples (>2%). On the other hand, sample M14 behaves as a loner (Fig. 7a), characterized by high concentrations of TiO_2 (like those of cluster A) and very low of Cr (like those of Cluster B), in addition to other compositional particularities, including the highest concentrations of Al_2O3, K_2O, Th, Nb, Zr, Y, and Ce in the analyzed set, and the lowest of SiO_2, MgO, and Na_2O (Table 3).

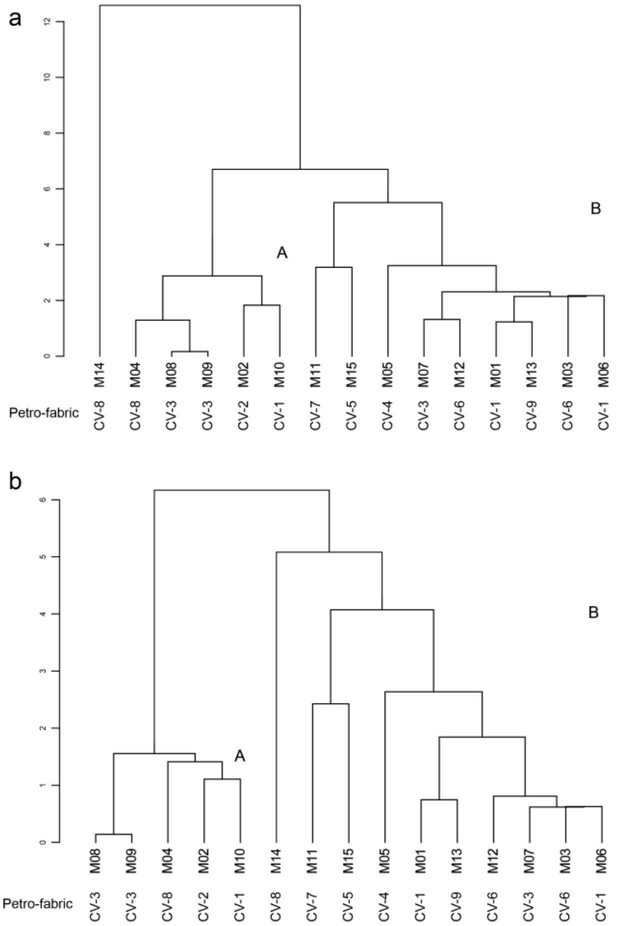

Figure 7. (a) Dendrogram resulting from cluster analysis (CA), using the centroid agglomerative method and the squared Euclidean distance, on 15 ceramic samples, based on the subcomposition Fe2O3, MnO, TiO2, MgO, CaO, Na2O, K2O, SiO2, Ba, Rb, Th, Nb, Zr, Y, Sr, Ce, Ga, V, Zn, Cu, Ni, and Cr, using Al2O3 as divisor in the log-ratio transformation of the data. Clusters A and B are indicated, as well as the petrographic data for each sample. (b) A second CA, performed on the basis of trace elements only (Ba, Rb, Th, Zr, Y, Sr, Ce, Ga, V, Zn, Cu, Ni, and Cr), using Nb as divisor in the log-ratio transformation of the data.

This first division obtained from CA does not, however, show a clear correlation with the fabrics defined by thin-section petrography (Fig. 7a). Each of the clusters and subclusters defined by CA shows significant internal heterogeneity in the composition of its samples, beyond the above-mentioned similarities in each of them. The only exception in the entire dataset appears to be the small group made up of two samples, M08 and M09, whose chemical and petrographic (fabric CV-3) compositions are very similar. Sample M04, apparently related to M08 and M09 in CA, shows however chemical differences from these (e.g., higher concentration of Fe_2O_3, K_2O, Rb, Zr, and lower Ba, Sr, and Cr) and, in addition, a different fabric (CV-8), with little mica compared to the very micaceous fabric CV-3.

A similar situation is noted when performing the multivariate statistical analysis considering only the trace elements, excluding Pb for the reasons already mentioned. The resulting cluster tree (Fig. 7b) is similar to that obtained in Fig. 7a, with minor differences. Thus, there is a lack of correspondence between chemical groups and petrographic fabrics, with the exception, again, of samples M08-M09, which are the only ones showing a close compositional similarity. By repeating the analysis after removing other trace elements that may be affected by processes of alteration and/or contamination (e.g., Sr and Cu) a lack of correlation with the petrographic evidence has again been obtained.

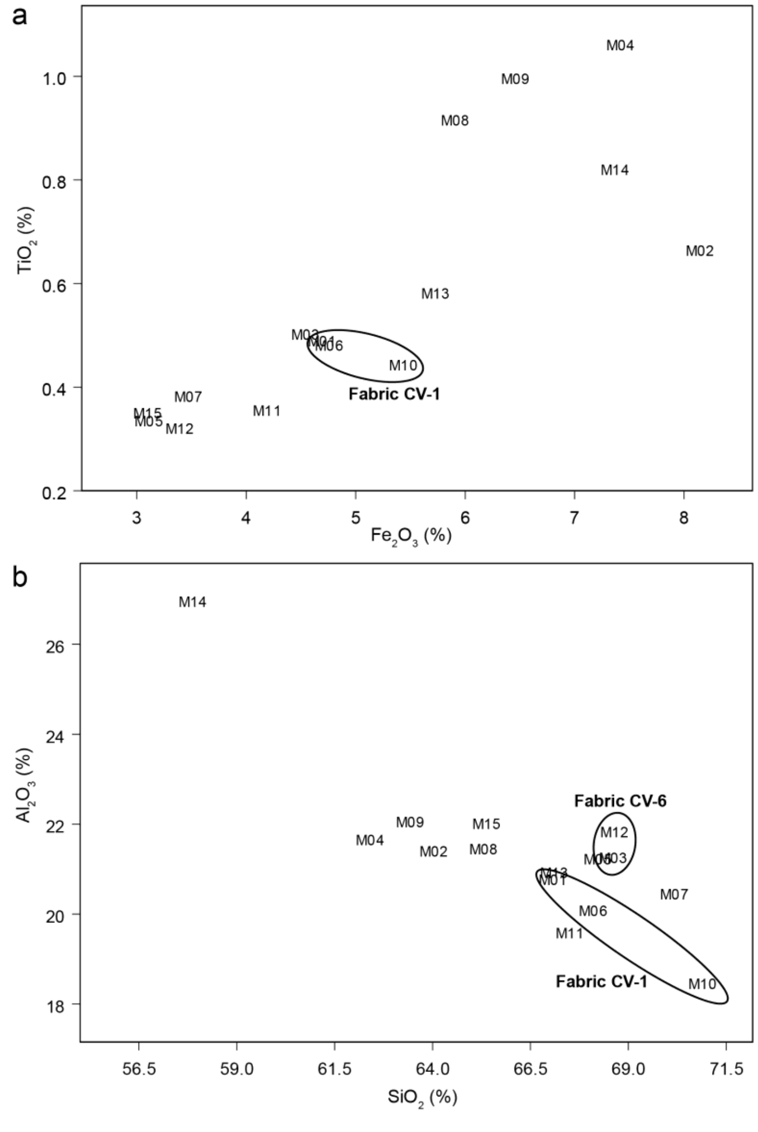

Figure 8. Binary diagrams, using normalized data, of Fe2O3 vs TiO2 (a) and SiO2 vs Al2O3 (b) for the 15 ceramic samples analysed.

In summary, two main conclusions can be drawn from the multivariate statistical analysis. First, there is significant internal compositional variability in the dataset, which is reflected in the fact that repeating statistical treatment considering various variables (e.g., excluding certain elements, or including only major elements or only trace elements), different groups are obtained in each case. These groups, in addition to not being consistent, are also not entirely homogeneous internally, accentuating the compositional variability of the dataset. The only exception is the group made up of samples M08 and M09. Secondly, in all multivariate analyses carried out, there is a lack of correlation between the chemical groups obtained and the petrographic fabric, again with the only exception of samples M08-M09, related to fabric CV-3.

Examination of chemical data (Table 3), indeed, suggests that samples with similar fabric tend to show clear differences in chemical composition. However, within this range of chemical variation, some similarities may be noticed. For example, among the three individuals of fabric CV-1 (M01, M06, and M10), there are differences in the concentrations of some elements (mainly in K_2O, Ba, Zr, Y, Cu, and Cr), but also similarities in the case of other elements, such as Fe_2O_3, TiO_2, Al_2O_3, or SiO_2, among others (Table 3). Something similar happens in the case of the two samples in fabric CV-6 (M03 and M12). In this way, while multivariate analysis does not allow for a clear correlation with petrographic fabrics, some patterns are noticed from certain chemical elements. Thus, for example, when examining the relationships Fe_2O_3-TiO_2 (Fig. 8a) and SiO_2-Al_2O_3 (Fig. 8b) some proximity is observed between the samples of fabric CV-1; also, the two samples in fabric CV-6 are close to each other in the bivariate diagram SiO_2-Al_2O_3 (Fig. 8b).

On the other hand, in the case of the three samples in fabric CV-3, two of them (M08 and M09) are very similar in composition, as mentioned above, but the remaining one, M07, shows a very different chemical composition (Table 3). Also, the two samples in fabric CV-8 (M04 and M14) are clearly different to each other in terms of elemental composition.

Table 3. Elemental composition of the 15 ceramic samples analysed through WD-XRF. Concentrations of major and minor oxides (and LOIs) are in percent; other minor and trace elements are in ppm.

Sample	Fe_2O_3	MnO	TiO_2	CaO	K_2O	P_2O_5	SiO_2	Al_2O_3	MgO	Na_2O	Ba	Rb	Th	Nb
M01	4,37	0,02	0,46	0,14	4,28	0,86	62,80	19,44	0,49	0,67	473	234	15	18
M02	7,47	0,02	0,61	0,16	3,28	0,25	58,85	19,68	0,96	0,55	316	186	15	18
M03	4,24	0,03	0,47	0,14	3,45	0,23	64,44	19,97	0,46	0,43	244	220	19	21
M04	6,84	0,02	0,98	0,29	3,75	0,84	57,72	20,03	1,34	0,57	307	213	22	26
M05	2,96	0,01	0,32	0,19	3,77	1,07	65,40	20,35	0,60	1,11	374	240	15	19
M06	4,46	0,03	0,46	0,30	3,84	0,41	64,20	18,93	0,70	0,84	306	222	21	21
M07	3,17	0,02	0,35	0,14	2,80	0,56	64,46	18,78	0,58	0,93	217	198	16	16
M08	5,52	0,03	0,86	0,32	3,26	0,61	61,27	20,12	1,14	0,57	483	160	15	19
M09	5,89	0,03	0,91	0,29	3,23	1,20	58,08	20,20	1,04	0,58	469	158	13	19
M10	5,01	0,01	0,41	0,13	2,92	0,25	65,63	17,08	0,68	0,39	230	160	11	14
M11	3,96	0,02	0,34	0,25	3,89	2,08	64,09	18,60	0,67	0,93	446	234	19	19
M12	3,16	0,01	0,30	0,12	3,77	0,21	64,36	20,46	0,52	0,76	300	222	12	17
M13	5,29	0,02	0,54	0,20	3,47	0,21	62,21	19,40	0,35	0,93	446	166	20	19
M14	6,61	0,01	0,74	0,07	5,04	0,51	52,02	24,23	0,32	0,22	396	270	45	31
M15	2,91	0,03	0,33	0,55	3,88	2,22	61,75	20,79	0,48	1,39	274	303	25	23

Sample	Pb	Zr	Y	Sr	Ce	Ga	V	Zn	Cu	Ni	Cr	LOI	SUM
M01	32	176	16	55	53	26	39	55	7	10	44	6,48	100,14
M02	40	161	14	42	53	25	60	116	17	20	53	7,31	99,26
M03	36	199	34	27	57	29	39	58	11	7	29	6,66	100,61
M04	33	229	34	36	61	29	80	80	23	28	87	7,48	100,00
M05	33	169	15	46	38	27	25	60	2	7	15	3,43	99,33
M06	38	225	37	40	63	27	31	66	8	8	18	6,03	100,32
M07	29	173	21	28	33	29	26	51	8	9	13	8,57	100,44
M08	30	186	29	59	64	24	72	70	23	34	120	6,07	99,92
M09	29	191	26	55	59	24	72	63	30	30	132	8,00	99,60
M10	24	125	16	41	70	24	47	59	24	16	41	6,60	99,20
M11	34	181	50	80	50	26	28	109	19	8	11	5,13	100,09
M12	48	147	19	35	35	29	24	83	9	6	14	6,63	100,41
M13	34	228	24	45	45	24	61	50	8	11	40	8,27	101,00
M14	35	308	79	40	98	33	61	51	5	6	8	11,41	101,33
M15	40	182	41	209	67	32	23	97	17	6	6	5,59	100,06

5. DISCUSSION: RAW MATERIALS AND PROVENANCE

The 15 ceramic individuals analyzed from Iron Age cylindrical vessels reflect, above all, general similarities in their compositional and technological characteristics. These are, in all cases, ceramics manufactured with non-calcareous clays and coarse and poorly selected granitic inclusions (Granitic Petrographic Group), sometimes together with a subordinate or accessory metamorphic contribution. The chemical (WD-XRF) and mineralogical (XRD) composition has, in all cases, general similarities that coincide with these petrographic characteristics, as previously explained. However, the existence of significant internal variability, within this group, in terms of petrographic fabrics and elemental compositions suggests the presence of a multiplicity of products or, strictly speaking, of 'Paste Compositional Reference Units' (PCRUs) (Bishop et al. 1982; Buxeda et al., 1995). The lack of a perfect correlation between the petrographic fabrics and the chemical groups defined could be the result of many different scenarios. This is a phenomenon which is not rare in coarse ceramics due to the heterogeneity of the raw materials themselves, as the presence of large mineral inclusions and rock fragments might have certainly an effect. The mixing of clays, or of a clay and a temper, could be another option, although in the petrographic observations we have not found evidence for clay mixing, normally denoted by the presence of streaks of different clays. In addition, the coarse (non plastic) inclusions could also be naturally included in the clayey sediment and not necessarily be the result of tempering, hypotheses that should be further investigated through additional studies on geological clays in the surroundings of the sites. For these reasons, further research is needed in order to explain the discrepancy between the petrographic fabrics and the chemical groups. This includes a survey of clayey sediments in the catchment areas of the sites involved, as well as experimentation with the clays (e.g. Liritzis et al., 2020; Xanthopoulou et al., 2020), which would help in a better characterization of the possible raw materials used by ancient potters and to define their natural variability, as well as to verify or discard possible clay mixing practices.

A variety of petrographic fabrics has been identified: five in San Cibrán de Las (CV-1, CV-2, CV-4, CV-6, and CV-8), one in Castromao (CV-3), one in Laias (CV-7), one in Armea (CV-5) and two in Santa Trega (CV-8 and CV-9). It is noteworthy, that the fabrics are different from one deposit to another and that we have not identified any fabric present in more than one site, with the only exception of fabric CV-8, whose two samples come from San Cibrán de Las and Santa Trega (Table 2). However, the chemical analysis does not support this relationship, since the composition of M14 and M04 is remarkably different (Table 3); they seem to show some similarity in the relationship Fe_2O_3-TiO_2 (Fig. 8a), but, as for other variables, the composition of M14 differs quite a bit from the whole analyzed set, which makes it always to behave as a loner in multivariate analysis (Fig. 7). For this reason, they should be considered as two distinct PCRUs. For the rest of the analyzed samples, the chemical data also appear to support that each fabric corresponds to a different PCRU (or more than one), without close and consistent chemical similarities between fabrics.

The two initial working hypotheses proposed either a production of all ceramic vessels in San Cibrán de Las, with subsequent distribution to the rest of deposits, or a local production in each settlement. Considering the integrated results of the analysis, the last hypothesis seems to be the more plausible, since the vessels collected at each site have different chemical-petrographic compositions compared to those from other sites. However, to better assess this conclusion, it is essential to examine the regional geology.

Four of the five sites included in this study, except for Santa Trega, are in the surroundings of the city of Ourense (Fig. 9). Both San Cibrán de Las and Armea are located on land with deposits of peraluminous granites with two micas, moderately leukocratic, while Laias, very close to the first (about 4 km away) stands on a granite formation of very leukocratic granites with two micas, but also with a facies with large biotite (ITGME 1988). In any case, regional geology shows a certain heterogeneity, so that, not far from these three sites, there are also important outcrops of other variants of granitic rocks (e.g., biotite-rich granites), as well as acidic metamorphic rocks. Unlike the previous ones, Castromao is located on a terrain of acidic metamorphic rocks, but almost on the edge with a large formation of granite rocks (Fig. 9). Santa Trega, on the other hand, is located further to the south-western part, in A Guarda (Pontevedra), at the mouth of the river Miño (Fig. 9). The site is located on terrains of granite with two micas, although very close to both metamorphic (schist and slate) and sedimentary (gravels, sands, clays) deposits (IGME 1985).

In San Cibrán de Las, the five fabrics defined in this study are compatible with the geology surrounding the site. Three of these fabrics (CV-1, CV-2, and CV-4), very rich in muscovite, relate to the use of leukocratic granitic materials, abundant in the area (Fig. 9) (ITGME 1988). The first two (CV-1 and CV-2) also have a relatively important acid metamorphic contribution. Metamorphic outcrops, although not very extensive, are found in various areas near the site, so it is not possible to specify more about the exact provenance area of the raw materials used. The difference between CV-1 and CV-2 seems to relate, above all, to the use of a clay richer in iron in the second, as evidenced by petrographic analysis, XRD and WD-XRF. In CV-4, the lower frequency of metamorphic inclusions and a relatively higher presence of heavy minerals indicates that the raw materials used are different, although they are compatible with the local geology. In contrast to these three highly muscovite granitic fabrics, in San Cibrán de Las there is also a granitic fabric with predominance of biotite, but also with frequent muscovite (CV-6), and a granitic fabric with much less frequency of micas (CV-8). The most biotite-rich granite outcrops are located east, west, and south of the site, i.e., in different sectors along the Miño Valley (Fig. 9). In short, these five fabrics in San Cibrán de Las can be considered different PCRUs, probably related to the use of different raw materials in each case, although all of them are compatible with the hypothesis of a local production.

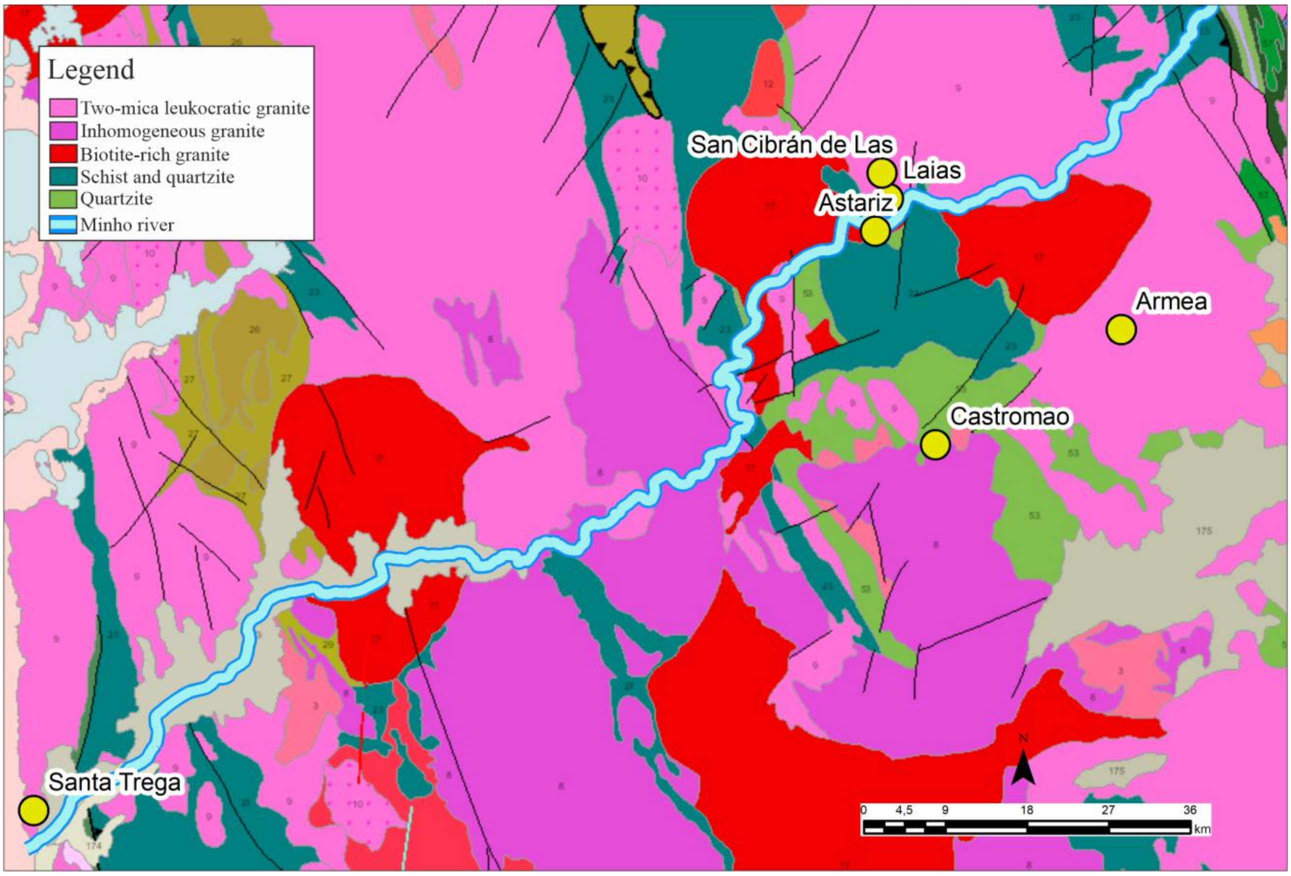

Figure 9. Geological map (based on IGME, 1985, and ITGME, 1988), with the sites studied.

Two of the fabrics in San Cibrán de Las (CV-1 and CV-6) are represented by more than one sample, and in both some variability in terms of the chemical composition of samples has been observed, reflected in multivariate statistical analyses (Fig. 7). However, the bivariate analysis has found relative homogeneity in the SiO_2-Al_2O_3 ratio for both fabrics and in the Fe_2O_3-TiO_2 ratio for CV-1 (Fig. 8). It should be noted that coarse-textured fabrics are being analyzed, whose heterogeneity can sometimes lead to certain limitations in chemical analysis (Maggetti, 1995). In conclusion, it is difficult now to determine whether CV-1 and CV-6 represent a PCRU in each case, or more than one PCRU, so the number of local products in San Cibrán de Las could be even higher than that resulting from the petrographic analysis.

In the case of Laias, a site located near the bank of the Miño River, the CV-7 fabric, documented in one sample from this site, is different from all those registered in San Cibrán de Las. Its composition makes it compatible with the geology of the area, both upstream and downstream in the Miño valley (Fig. 9). Being Laias and San Cibrán de Las neighboring settlements, it is not possible to know with absolute certainty the origin of this fabric, but it could be a local production.

The CV-5 fabric, identified in Armea's only sample (M15), is very rich in muscovite and lacks metamorphic inclusions. The site is located on moderately leukocratic granite outcrops, and with very leukocratic granite deposits to the northeast and southeast (Fig.

9), which makes this fabric compatible with local production. The lack of a clear petrographic and chemical relationship with individuals from other deposits also seems to support this conclusion.

In the case of Castromao, the three ceramic vessels analyzed (M07 to M09) showed a similar fabric (CV-3), very rich in muscovite, albeit with a common presence of biotite, and a subordinate metamorphic contribution. While Castromao is placed strictly on metamorphic rock soils, comparison with local geology suggests that the raw materials used would come either from the granite outcrops south of the site, or from the granites of two micas that emerge to the west and (somewhat more distant) east of it (Fig. 9). It should be noted that the chemical analysis detects two distinctly different compositions, since the sample M07 on the one hand, and the samples M08-M09, on the other hand, present significant differences in the concentrations of several major, minor, and trace elements (Table 3; Fig. 7-8). While some chemical variability cannot be ruled out within the same fabric, in this case, however, it is difficult to conclude that it is the same PCRU. It should be noted that the petrographic description of the CV3 fabric noted some minor features in the case of M07, such as a slightly coarser texture than in M08-M09, a slightly higher frequency of plagioclase and a greater presence of clay lumps. Therefore, we may be faced with two different PCRUs, for which very similar raw materials were used, but with some differences mainly at the chemical level. Both PCRUs, in any case, could be local products.

Finally, in Santa Trega, fabrics CV-8 and CV-9, identified in two samples (M14 and M13, respectively), reflect the use of granitic materials with relatively low presence of micas (biotite and muscovite), and a low metamorphic contribution. The composition is compatible with local geology (Fig. 9) (IGME 1985). The two differentiated petrographic fabrics, which also have clear chemical differences between them (Table 3; Fig. 7-8, would most likely represent two different PCRUs.

6. ARCHAEOLOGICAL IMPLICATIONS OF THE DATA

One of the main problems for the study of ceramic production in the Iron Age in northwestern Spain is the lack of clear archaeological evidence about the different stages of the production process. Owing to this lack of archaeological evidence, ethnoarchaeological and archaeometric approaches have been attempted, but there is still much work to be done. Except for a doubtful lump of clay (González Ruibal, 2006, 466; Rey Castiñeira, 2011, 35), no information exists about the forming method. No consensus exists about the date when the wheel was introduced, and the 4th century BC (Rey Castiñeira, 1986, 192, 2011, 24) and the closing phase of the Iron Age (Pérez Rodríguez-Aragón, 2017; Cobas Fernández and Prieto Martínez, 1999, 79; González Ruibal, 2007, 19, 494) have been proposed. It has been suggested that peasants made their own vases, following again the models posed by traditional pottery-making (Rey Castiñeira, 2011; García Alén, 1983); and around the turn of the Era, these domestic producers had achieved considerable skill. This task would complement other work, such as tilling the fields and looking after livestock in the interior, and the exploitation of sea resources in the coastline. A domestic production regime could explain internal differences between the final products (which are present in the case of cylindrical vases, according to the analytical results); individual production tends to favor the use and mix of specific raw materials, and even the emergence of unique decorations and shapes.

To date, no kilns have been identified with certainty, but a grille found in the upper area of Laias has been interpreted as one (Álvarez González and López González, 2000) and experiments have been undertaken to explore the possibility that the so-called portable kilns of Castromao operated as ceramic kilns (Rey Castiñeira et al., 2013; Teira Brión et al., 2013). The most plausible hypothesis is that open kilns, which leave little archaeological trace, were used. We may think about collective firing in communal kilns (as is still done in the context of traditional potting), to which each participant contributes with their share of firewood. Specialists with advanced knowledge on firing probably directed and coordinated the process, since this is one of the most delicate steps, and production may be lost in case of mishap. Considering that, to date, no kilns have been found in the *castros*, it is likely that these tasks took place in the periphery of the settlement or in a specific communal area, reducing the risk of fire. As such, the Iron Age pottery workshops in the northwest remain to be found, and the earliest known workshops are still those installed during the Roman period, in *Lucus Augusti* and *Bracara Augusta*.

Ceramic production in the sites under study is framed by the so-called 'pottery area of the Miño', which includes the sites located in the middle course of the Miño River (Rey Castiñeira 1991, 412-413, 2014, 289). The valley of the Tea was a point where the Rías Baixas and Miño traditions overlapped, as illustrated by the sites located in the river mouth (e.g., Santa Trega). The concept of pottery areas works especially well for the second Iron Age, but in the turn of the Era the boundaries appear to be much more permeable to the circulation of objects and ideas. Preliminary observation based exclusively on shape has allowed us to identify a large number of shapes that are traditionally associated with the Miño repertoire in *castros* situated in the Rías Baixas. We find interior and exterior handles in Trega (De la Peña Santos, 1986) and Castro de Vigo (Hidalgo Cuñarro, 1985), and the d-profile little pans of Montealegre (Vidal Lojo and Naveiro López 2020, 275), the large orangey jars, and the cylindrical vases analyzed here in Trega (Rodríguez Nóvoa, 2017). It is unclear whether these pieces were traded to the coastal *castros* or whether they were, like the cylindrical vases, local productions. Analytical data suggests that what was moving was not the pieces themselves, but shared ideas and tastes. It would be desirable to apply archaeometric analyses to other objects that are traditionally associated with the middle basin of the Miño in order to determine if the coastal *castros* independently produced other Miño models (that is, if they shared the shape) or if some pieces were, in fact, traded. It is also possible that this situation reflects multiple solutions, such as the occasional import of some pieces to serve as models for local productions. Another option, harder to test archaeologically, is the operation of itinerant potters producing a similar repertoire in different areas, like glass blowers and mosaic-builders in the Roman period. The small size of the sample prevents us from backing any of these alternatives; a wider program of archaeometric analysis would be necessary to expand the database. At any rate, the northwest appears as a dynamic area, in which *castros* in different subareas kept intense contacts, through the exchange of goods or/and ideas.

From the late 1st century BC, we witness a gradual opening and expansion of exchange networks in the northwest of the Iberian Peninsula (exchange not only of goods, but also ideas). The valley of the Miño was a major route, facilitating the penetration towards the interior of products arrived by sea, and channeling products from the interior towards faraway markets. The interior of modern Galicia was a key source of metals, like tin and gold, so it played a major role for seaborne commercial exchange. This explains the presence of the earliest imported materials in the castros of the middle basin, like the aryballos from Riós or the Italian *terra sigillata*, which may have been exchanged for metals. These luxury items were unloaded in the major coastal harbors, like the *castros* in the *ría* of Vigo or the mouth of the Miño, where Santa Trega is situated, and a small proportion of these goods would be redistributed in the interior. According to formal analysis, and while we await for more analytical evidence, few coarse wares produced in the *castros* of Rías Baixas have been found in the interior, aside from a doubtful Forca jar in the *castro* of San Millán (López Cuevillas and Taboada Chivite, 1958).

Concerning cylindrical vases, the number of specimens found outside the San Cibrán-Astariz-Laias nucleus is small. This could be due to a lack of specific study and publication or, in fact, suggest that local imitations of this shape outside its core area were rare.

7. CONCLUSIONS

From the analytical study of 15 Iron Age cylindrical vessels in the Miño valley, the general similarities observed in the petrographic and chemical composition suggest the existence of the same ceramic tradition in terms of the type of materials used and manufacturing techniques, including the use of non-calcareous clays mixed with roughly similar granitic inclusions. However, based on more or less pronounced petrographic and/or chemical differences between these individuals, it has been possible to identify a multiplicity of 'Paste Compositional Reference Units' (PCRU) in the ceramic assemblage represented in the sampling.

Considering the regional geology, each of the PCRU differentiated in this study is compatible with a local production at the site from which the materials analyzed were collected. The fact that no PCRU represented in more than one site could be detected suggests that the cylindrical vessels were locally produced at each settlement following the same type or model, which could perhaps have its origin or at least be more represented in San Cibrán de Las. On the other hand, the hypothesis that the vessels were produced only in San Cibrán de Las and distributed to the rest of the settlements in the region seems very difficult to be sustained based on the analytical evidence.

The results of these analyses have yielded important information that will allow us to know this type better, and, above all, increase our knowledge about the characterization of ceramics and its economic-commercial dynamics of the final phase of the Iron Age in the northwest of the Iberian Peninsula.

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AUTHOR CONTRIBUTIONS

Archaeometry analysis: LF and MACO; archaeological study: AARN and AFF, conceptualization and writing: AARN, LF, AFF and MACO. All authors have read and agreed to the published version of the manuscript.

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