Hispanic *terra sigillata* productions documented on the Catalan coast: Some unexpected results and new issues

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**Abstract** - Archaeological research has recovered significant amounts of Hispanic *terra sigillata* (HTS) dated back to the 1st century AD on the Catalan coast, an area traditionally considered within the influence of Gaulish *sigillata* during that period. Moreover, several new HTS workshops have also been recently discovered in this area. In order to shed light on the provenance and exchange structures of HTS, 86 samples from the sites of *Baetulo*, *Emporiae*, and *Tarraco* were analysed by means of WD X-ray fluorescence (WD-XRF), X-ray diffraction (XRD), and scanning electron microscopy (SEM). The results show that almost no HTS from workshops other than Trício, located inland, were commercialised on the Catalan coast, in spite of the proximity of other workshops.

1. Introduction

Traditionally, Hispanic *terra sigillata* (HTS) has been considered an early Empire minor production, made and distributed from the mid-1st to the mid-2nd century AD in those places where Gaulish *sigillata* was not at all, or only scarcely, commercialised, i.e., the inland area of the Iberian Peninsula (Romero Carnicero 1985; Tuset i Bertran 1991; Buxeda i Garrigós 1995). However, this view has changed recently, owing to the discovery of a large number of workshops, some of them located near the coastline, as well as to the identification of HTS from the Trício complex on the Catalan coast.

The archaeological evidence related to the production of HTS has been increasing lately in Catalonia (Fig. 1). Thus, to the early discovered workshops of Abella and the probable one of Solsona (Buxeda i Garrigós 1995; 1999), newly recovered remains, mostly moulds and HTS, have been added, and these indicate the production of HTS throughout the territory (Madrid i Fernández 2005). These workshops produced solely HTS, while Abella produced only Advanced HTS (AHTS), dated back to the period between the mid-2nd century and the 3rd century AD. Among these recently discovered finds, moulds and HTS from Lleida (Pérez Almoguera 1990), Montroig del Camp (Pallejà i Vilaseca 1994), and la Bòbila d’Ermedàs (Casas i Genover et al. 1990) were first analysed in order to define their reference group (Buxeda i Garrigós and Madrid i Fernández 2000; Madrid i Fernández 2005; Madrid i Fernández and Buxeda i Garrigós 2007).

On the other hand, Trício (and the so-called Trício complex/area), located inland, is nowadays considered as one of the most significant production centres of HTS in the Iberian Peninsula. Here, archaeological remains such as kilns, dumps, moulds, and above all stamps showing more than one hundred different names have enabled the identification of more than 15 different workshops and an estimated number of a hundred of potters who would have worked in this complex (Saénz Preciado and Saénz Preciado 1999). Moreover, the Trício complex is the only production centre known to have produced Hispanic *terra sigillata* (HTS), Advanced HTS (AHTS), and Late HTS (LHTS), this latter type being produced in the 4th-5th centuries AD. Finally, it must be added that there are only a few archaeometric studies related to the distribution of HTS, but these have shown a predominance of materials from Trício in all the consumption centres analysed (Picon 1984; 1985; Madrid i Fernández 2005; Madrid i Fernández and Buxeda i Garrigós 2002).

2 Sampling and analytical techniques

In spite of the research mentioned above, we are still far from a clear understanding of the role played by all these workshops in the exchange and consumption patterns of HTS on the Catalan coast. Therefore, the goal of this archaeometric study is to identify how many HTS productions were commercialised in this area, and from which workshops, as well as to provide more information on the technology used for their production. In this sense, the study also aims to examine in more depth the concept
of quality, in order to verify whether HTS was not as good a product as Italian and Gaulish sigillata, as the current archaeological assumptions maintain, or whether this is not the case.

Thus, chemical analyses by means of wavelength dispersive X-ray fluorescence (WD-XRF) and mineralogical analyses by means of X-ray diffraction (XRD) were performed on 86 samples from the consumption sites of Baetulo,
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Table 1. Mean and standard deviation (normalised data) of TSH1 and Tricio *terra sigillata* productions. *Values in brackets are averages calculated using only individuals free of analcime (n=37).

<table>
<thead>
<tr>
<th></th>
<th>TSH1 (n=2)</th>
<th>TRICIO (n=73)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean St.dev</td>
<td>Mean St.dev</td>
</tr>
<tr>
<td>Na₂O (%)</td>
<td>0.75 0.01</td>
<td>0.92(0.64) 0.44(0.07)</td>
</tr>
<tr>
<td>MgO (%)</td>
<td>3.32 0.09</td>
<td>3.19 0.45</td>
</tr>
<tr>
<td>Al₂O₃ (%)</td>
<td>22.36 0.15</td>
<td>19.74 0.83</td>
</tr>
<tr>
<td>SiO₂ (%)</td>
<td>48.37 0.05</td>
<td>55.59 1.45</td>
</tr>
<tr>
<td>P₂O₅ (%)</td>
<td>0.23 0.07</td>
<td>0.19 0.1</td>
</tr>
<tr>
<td>K₂O (%)</td>
<td>4.23 0.03</td>
<td>3.52(3.96) 0.68(0.21)</td>
</tr>
<tr>
<td>CaO (%)</td>
<td>10.66 0.14</td>
<td>9.54 1.53</td>
</tr>
<tr>
<td>TiO₂ (%)</td>
<td>0.82 0.02</td>
<td>0.79 0.03</td>
</tr>
<tr>
<td>V (ppm)</td>
<td>115 2</td>
<td>83 6</td>
</tr>
<tr>
<td>Cr (ppm)</td>
<td>109 6</td>
<td>101 8</td>
</tr>
<tr>
<td>MnO (%)</td>
<td>0.08 0</td>
<td>0.05 0.01</td>
</tr>
<tr>
<td>Fe₂O₃ (%)</td>
<td>8.99 0.1</td>
<td>6.29 0.25</td>
</tr>
<tr>
<td>Ni (ppm)</td>
<td>59 2</td>
<td>40 3</td>
</tr>
<tr>
<td>Cu (ppm)</td>
<td>61 4</td>
<td>28 7</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>169 11</td>
<td>101 6</td>
</tr>
<tr>
<td>Ga (ppm)</td>
<td>28 3</td>
<td>26 2</td>
</tr>
<tr>
<td>Rb (ppm)</td>
<td>153 13</td>
<td>170(205) 46(15)</td>
</tr>
<tr>
<td>Sr (ppm)</td>
<td>189 16</td>
<td>329 64</td>
</tr>
<tr>
<td>Y (ppm)</td>
<td>27 4</td>
<td>27 3</td>
</tr>
<tr>
<td>Zr (ppm)</td>
<td>134 10</td>
<td>171 13</td>
</tr>
<tr>
<td>Nb (ppm)</td>
<td>15 4</td>
<td>19 1</td>
</tr>
<tr>
<td>Ba (ppm)</td>
<td>656 83</td>
<td>571 53</td>
</tr>
<tr>
<td>Ce (ppm)</td>
<td>67 9</td>
<td>74 8</td>
</tr>
<tr>
<td>Pb (ppm)</td>
<td>37 7</td>
<td>50 21</td>
</tr>
</tbody>
</table>

XRD measurements were performed with the same prepared powder of the above specimens with the help of a Siemens D-500 diffractometer working with Cu Kα radiation (\(\lambda = 1.5406\) Å) at 1.2 kW (40 kV, 30 mA), and using a graphite monochromator in the diffracted beam. Spectra were recorded from 4 to 70° 2θ, at 1° 2θ/min (step size = 0.05° 2θ; time = 3 s). Crystalline phases were evaluated using the DIFFRACT/AT program of Siemens, which includes the International Centre for Diffraction Data – Joint Committee of Powder Diffraction Standards (ICDD-JCPDS) data bank.

The SEM study was conducted on a fresh fracture (transverse to the wall and parallel to the vertical dimension of the vessel) obtained from each of the selected pieces. The samples were carbon coated and examined under a Jeol JSM-840 SEM coupled to an energy dispersive X-ray analyser (EDX) (Madrid i Fernández 2005; Madrid i Fernández and Buxeda i Garrigós 2007).

### 3 Chemical analysis

The results of the chemical analysis carried out by XRF correspond to a special case: the \(d + 1\)-dimensional vector space that arises from the \(d\)-dimensional projective space, the simplex \(S^d\), in which the projective points are represented by homogeneous coordinates with a constant sum \(k (k \in \mathbb{R}^+)\): (R\(^{+}\): the set of positive real numbers):

\[
\begin{aligned}
    x &= [x_1, \ldots, x_{d+1}] | x_i \geq 0 (i = 1, \ldots, d + 1), \\
    x_1 + \ldots + x_{d+1} &= k
\end{aligned}
\]

(in this case \(k = 100\), and its vector space is the positive orthant, which follows a multiplicative model with a logarithmic intervals metric (Barceló-Vidal et al. 2001; Aitchison 2005; Buxeda i Garrigós 2008). Therefore, the original chemical data \(x\) have been transformed to \(z\) using the centred log-ratio transformation (CLR), in order to obtain an Euclidean space, removing the restriction to the constant sum \(k\) and avoiding the effects of possible contaminations, in which any standard statistical technique can be applied:

\[
x \in S^d \rightarrow z = \ln \left( \frac{x}{g(x)} \right) \in \mathbb{R}^{d+1}
\]
where $S^d$ is the d-dimensional simplex, and $g(x)$ is the geometric mean of all the $d + 1$ components of $x$ (Aitchison 1986; Buxeda i Garrigós 1999; 2008).

The results of the data treatment can be summarised in the dendrogram of the cluster analysis (Fig. 2), performed using the components Na$_2$O, MgO, Al$_2$O$_3$, SiO$_2$, K$_2$O, CaO, TiO$_2$, V, Cr, MnO, Fe$_2$O$_3$ (as total Fe), Ni, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, and Ce log-ratio transformed using the CLR transformation. The cluster analysis has been performed with the S-Plus statistic software (MathSoft 1999), employing the squared Euclidean distance and the centroid agglomerative algorithm. In order to establish the provenance of the analysed samples, chemical results were compared against the ARQIUB archaeometric database of Hispanic terra sigillata productions, which includes individuals from the main production centres of the Iberian Peninsula. Statistical treatment shows that most of the HTS individuals from the three sites can be attributed to Tricio (73 out of 86 analysed samples), demonstrating the influence of this centre on the coastal areas as well, even though the great influence of Gaulish sigillata during the same period is also certain and proved by archaeometric studies (Table 1) (Madrid i Fernández 2005; Madrid i Fernández et al. 2005). A few further specimens might also be attributed to the Tricio complex, even if slight chemical differences have been observed. Finally, two individuals form part of a production of unknown provenance, called TSH1, while a further two remain as unclassified singles, also after being compared against the ARQIUB archaeometric database of general terra sigillata productions, which includes, in addition to the Hispanic types, the most popular productions of the Italian Peninsula (Arezzo, Pisa, Pouzzoloni, A Production of the Bay of Naples), South Gaulish centres (La Graufesenque and Montans), and Eastern Mediterranean centres (Eastern sigillata A), among others.
Chemical results show that all the analysed samples correspond to calcareous ceramics (CaO \( \approx 5-6\% \)). Normally the high content of CaO is due to a significant presence of calcite, which effectively decomposes at about 850°C. This decomposition favours the crystallisation of high temperature calcium-silicates and calcium-aluminium-silicates, as well as the emission of CO\(_2\), causing the development of a cellular microstructure (Maniatis et al. 1981; 1983). In the present case, the study of the XRD diffractograms allowed the identification of several fabrics within each production according to the mineralogical phases recognised.

The study of the XRD diffractograms of the individuals attributed to Tricio allowed the identification of six fabrics (F1 to F6), corresponding to three different Equivalent Firing Temperatures (EFT) (Picon 1973): F1 and F2 (800/850°C – 950/1000°C) (illite-muscovite, crystallisation of pyroxene and gehlenite), F3 (around 950/1000°C) (almost total decomposition of illite-muscovite and gehlenite, decomposition of calcite, crystallisation of plagioclase), and F4, F5, and F6 (>950/1000°C) (decomposition of gehlenite, further development of pyroxene and plagioclase; in F6, crystallisation of analcime is observed) (Figs. 3a, b and c). In spite of this dispersion, it must be said that only 13 individuals are included in the first three types of fabric (1 in F1, 1 in F2, and 11 in F3), whereas all the others are included in the fabric types F4 to F6. This aspect suggests a high degree of control of the firing process by the potters of Tricio. On the other hand, the XRD diffractograms of the two individuals of the TSH 1 production are very similar and their study allowed estimating an EFT between 850 and 950/1000°C.
Based on these results, examination by SEM of the fresh fracture surface of individuals from Tricio (fabrics F1, F3 and F6) and of the TSH 1 productions were undertaken in order to study the microstructure and sintering state of the matrix, and the adherence and sintering state of the gloss. As shown in Figures 4 and 5, the degree of vitrification of the matrix increases gradually with firing temperature, and a cellular microstructure is developed. These results are in good agreement with those reported by Maniatis and Tite (1978/79) for the microstructures developed by calcareous ceramics. Then, focusing on the Tricio production, the matrix of F1 (Fig. 4a), for which a lower EFT (800/850°C–950/1000°C) was estimated, corresponds to an initial vitrification state; as the temperature rises, vitrification progresses, and the extent of glass phase increases; thus, the matrix of F3 (Fig. 4c), for which the EFT was estimated around 950/1000°C, corresponds to a continuous vitrification state; finally, the matrix of F6 (Fig. 4e) shows an advanced continuous vitrification state, indicating that the EFT exceeded 950/1000°C, and would probably have been between 1050 and 1150°C. With regard to the TSH 1 production, the matrix (Fig. 5a) shows a continuous vitrification state, narrowing down the EFT estimated by XRD to around 950/1000°C. Regarding the glosses, those of the Tricio productions exhibit thicknesses between 10 and 15 μm, a total vitrification state (Fig. 4d and f), and good adherence to the matrix. The only exception is the individual belonging to F1 (Fig. 4b), which is not completely vitrified. In the case of the TSH 1 production, the thickness of the glosses is 20 μm (Fig. 5b and c), and they exhibit bad adherence to the matrix. Moreover, some areas are completely vitrified, but others still present a large number of discernible particles due to incomplete vitrification. This could be explained by the use of a clay grain size larger than appropriate for this type of glosses, together with the considerable body thickness and a firing temperature that did not exceed 950–1000°C.

In summary, the technological study shows that the Tricio production must be considered as a good quality ware, made using radiation kilns (i.e., muffle-like furnaces) and high firing temperatures, in a similar manner to Gaulish productions (Sciau et al. 1992; Sciau and Vezian 2002). Although three different EFTs could be estimated, most of the individuals are in the 1050–1150°C range. Gloss thickness is around 10–15 μm. It is well vitrified and shows a good adherence to the matrix, thus being waterproof, which was the main quality required. Regarding Gaulish productions (Bémont and Jacob 1986), we must remember that the La Graufesenque workshop, the main rival of the Hispanic sigillata in the markets of the Iberian Peninsula, made high quality terra sigillata from calcareous clays (Picon 1990) fired in radiation kilns in a temperature range of 1050–1150°C, and showing a gloss around 10–15 μm thick, well vitrified, with a good adherence to the matrix (Madrid i Fernández 2005; Madrid i Fernández et al. 2005); i.e., the same characteristics as those of the HTS analysed in this study. Thus, it is not surprising that HTS could rival the Gaulish productions in the markets, since HTS is a fine ware of similar quality.

On the other hand, the TSH 1 production was most probably also made using radiation kilns. The estimated EFT is around 950–1000°C. Gloss thickness is 20 μm, and it is unevenly preserved; it was made by using a larger clay grain size than appropriate for this type of glosses. For this reason, some areas remain incompletely vitrified.

5 Final remarks
None of the production centres located in the Catalan area previously studied by archaeometric research (Lleida, Abella, Bóbila d’Ermedàs, and Montroig del Camp) has been identified among the Hispanic terra sigillata individuals analysed in this study. The truth is that there are almost no HTS from workshops other than Tricio (and Tricio’s area) on the Catalan coast, with the exception of two samples grouped together in the TSH 1 production, and two more singles that remain unclassified. It must be kept in mind that Lleida, Abella, Bóbila d’Ermedàs, and Montroig del Camp had produced good quality HTS by using radiation kilns.

The firing process in a radiation kiln, known as modus C process (Picon 1973), implies that the atmosphere in the firing chamber is always oxidising, both during the firing process itself and during the cooling process. In these kilns, flames and smoke go straight from the firing chamber to the outside through interconnecting tubes. In this way, flames and smoke are never in contact with pottery, rendering this type of kilns the first muffle-like furnace in history. Furthermore, the fact that the atmosphere is always oxidising facilitates the growth of hematite crystals, conferring to the pottery the characteristic red colour of the terra sigillata production. Such workshops would involve a higher investment in resources for pottery production, because their complex structure would need twice or three times the quantity of fuel required for firings in a single convection kiln, as well as highly specialised know-how. Therefore, we may assume that these centres made terra sigillata fired in modus C because they expected to achieve a wide distribution and financial returns (Picon 2002). For this reason, it is surprising that not even one individual from these Catalan workshops has been identified so far at any of the three neighbouring cities analysed in this study, which were assumed to be possible reception centres.

This finding appears even more astonishing if we bear in mind that the cities analysed in the present study are known to have been part of extensive trade networks; Emporiae as a crucial centre for the entry and redistribution of great quantities of goods originating mostly from the Italian Peninsula, already from the end of the 2nd century BC (Aquilué Abadías et al. 1984; Aquilué et al. 2002); Tarraco as the capital of the province of Hispania Tarraconensis from the end of the 1st century BC (Macias i Solé 1999); and Baetulo, whose main economic activity, developed from the second half of the 1st century BC onward, was wine production, exported principally to Gaul. This activity would allow Baetulo a similar position to that of other large cities within the trade network of the western Mediterranean (Comas i Solà 1991). Thus, future research on these workshops should be undertaken in order to identify their role in the commercialisation of HTS. It should be investigated whether these workshops actually commercialised sigillata or not, and, if so, which were their influence areas and the
locations to which their products were distributed. Most of them also produced other materials, such as coarse ware or construction supplies, even at a large scale, according to the archaeological finds. Perhaps they considered producing terra sigillata because it was a successful artefact. However, there is also the possibility that after an assay phase and taking into account the production costs, they finally decided to abandon this production and, as a result, their products were not commercialised in the neighbouring cities of Baetulo, Emporiae, and Tarraco. In any case, the absence of their products in consumption centres raises new and interesting issues for archaeological research.

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