Archaeometric characterisation of amphorae from the Late Antique city of *Iluro* (Mataró, Spain)

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ABSTRACT

A large number of transport amphorae coming from various Late Antique archaeological contexts in Mataró (Catalonia, Spain) have been analysed, in order to characterise the materials, investigate the diversity of fabrics and shed light on their provenance. A total of 96 individuals were subjected to petrographic (OM), chemical (XRF) and mineralogical (XRD) analysis. The results prove that the majority of the amphorae are related to a northern African provenance (Tunisian mainly), with several different fabrics that, in some cases, can be associated with specific production centres. Also a large number of southern Hispanic fabrics, in particular from the Baetican area, have been identified. In addition, some eastern Mediterranean and Balearic fabrics have been characterised, as well as a few fabrics for which a local/regional production can be proposed. The results indicate the presence of many different chemical-petrographic compositions from each of these regions and provide, thus, an insight into the variety of transport amphorae that arrived to the Late Antique urban centre of *Iluro*.

KEYWORDS: amphora, Hispania, Late Antiquity, provenance, petrography, XRF, XRD

1. INTRODUCTION

Several excavations conducted during the last decades —especially from the 1980s— in the urban centre of Mataró (Catalonia, Spain) provided significant evidence of the Roman city of *Iluro* (Figure 1), which continued to be occupied during Late Antiquity, known as *Alarona* possibly from the 5th-6th centuries (Cerdà et al., 1997;

Cela and Revilla, 2004; Revilla, 2011). Large pottery assemblages were uncovered, including hundreds of Late Roman amphorae as well as other import products (fine ware, cooking wares, etc.) that show an important trade activity in the area, considering that this was a relatively small secondary urban centre in *Hispania Tarraconensis*. The supplying with these imports must have taken place through a secondary network, most probably from the port of *Barcino*, since no ancient port has been documented so far in *Iluro* or its surroundings (Cerdà et al., 1997; Cela and Revilla, 2004).

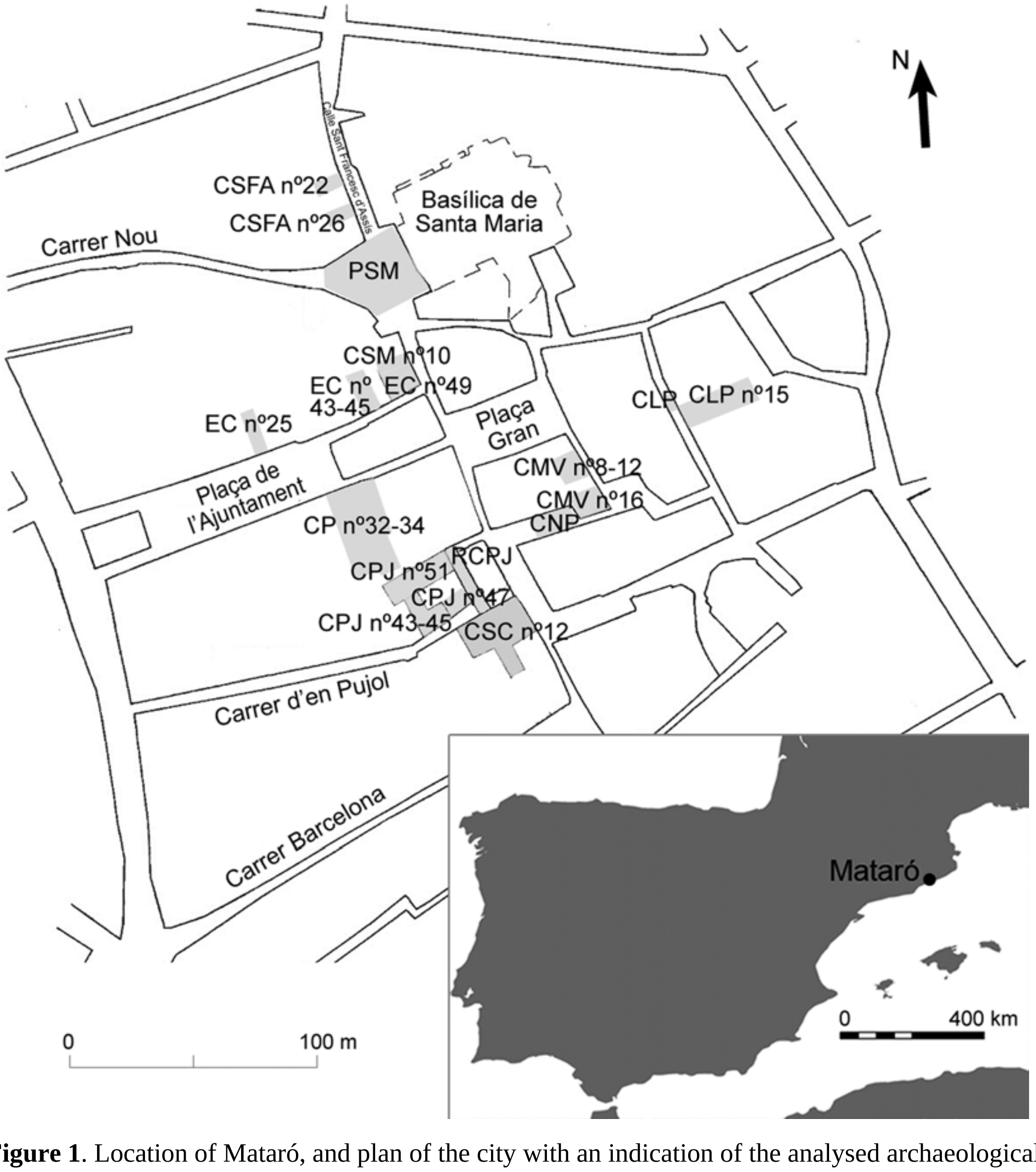

Figure 1. Location of Mataró, and plan of the city with an indication of the analysed archaeological contexts (modified from Cela and Revilla, 2004). Abbreviations: CLP, Carrer La Palma; CMV, Carrer Magí de Vilallonga; CNP, Carrer Na Pau; CP, Carrer Palau; CPJ, Carrer d'en Pujol; CSC, Carrer de Sant Cristòfol; CSFA, Carrer Sant Francesc d'Assis; CSM, Carrer Santa Maria; EC, El Carreró; PSM, Plaça de Santa Maria; RCPJ, Recolzada del Carrer d'en Pujol

The analysis of transport amphorae (related to the trade of oil, wine, fish sauces and other products) can provide important information about the commercial dynamics of this centre in the Late Antiquity. In this paper, we present the results of the archaeometric characterisation of amphorae found in various contexts from Mataró, dated from the late 3rd/early 4th century to the 6th century. This is one of the case studies within the framework of a larger project on the characterisation of Late Roman Pottery in the Western Mediterranean (LRPWESTMED) where the amphorae in northeastern Spain are a particular case study (*e.g.* Fantuzzi et al. 2015a, 2015b).

The analysis focuses on the characterisation and provenance of the materials, as well as on some general technological aspects. The aim of the study is to provide new evidence on the archaeometric characterisation of Late Roman amphorae, examine the diversity of fabrics represented in *Iluro* and investigate their provenance. Through this study, we aim to shed more light on the variety of imports that were arriving to this consumption centre in Late Antiquity from other Mediterranean regions, as an evidence of the trade networks in which this coastal centre was inserted.

2. MATERIALS AND METHODS

Amphorae from various archaeological contexts in the urban centre of Mataró (Figure 1) and associated with Late Antique *Iluro* were considered for archaeometric analysis. A total of 96 individuals were sampled (Table 1). It should be pointed out that six of these individuals (PAL007, 008, 012, 013, 014, 060) had already been subjected to a first analysis by Buxeda and Cau (2004), within a larger study focused on the analysis of cooking and common wares from a Late Antique context in Mataró.

We attempted to make the sampling as representative as possible of the frequencies of each amphora type in the archaeological assemblage. According to the archaeological study (Cerdà et al., 1997; Cela and Revilla, 2004; Revilla, 2011), they correspond mainly to African and southern Hispanic materials, with a wide range of amphora types being represented (Table 1). In addition to these samples, a few possible local/regional products and some imports from other areas (eastern Mediterranean and the Balearic Islands) were also considered for analysis. The most represented amphora types are illustrated in Figure 2 (for illustrations of all the analysed amphorae, see Appendix A).

Sample	*Amphora type*	*Sampled part*	*Archaeological context*	*Chronology of SU*
ILU001	Dressel 23a / Keay 13A	Rim	c/ Sant Cristòfol nº 12	300-325 AD
ILU002	Indeterminate	Rim	c/ Sant Cristòfol nº 12	300-325 AD
ILU003	Dressel 23¿c? / simile Tejarillo II	Rim	c/ Sant Cristòfol nº 12	300-325 AD
ILU004	Keay 16A or Almagro 50	Rim	c/ Sant Cristòfol nº 12	300-325 AD
ILU005	Keay 25.¿3? (var. ¿L?)	Rim	c/ Sant Cristòfol nº 12	300-325 AD
ILU006	Africana IIA / Keay 4-5	Rim	c/ Sant Cristòfol nº 12	300-325 AD
ILU007	African indeterminate	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU008	African indeterminate	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU009	Keay 11 / Tripolitana III	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU010	Keay 25.3 or *Spatheion* 1	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU011	Keay 25.1	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU012	Keay 25.2	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU013	Keay 25.1	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU014	Keay 25.1 or *Spatheion* 1	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU015	Keay 25.2	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU016	Keay 27¿A?	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU017	¿Keay 27A? ¿Keay 7/25.1?	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU018	Keay 35B	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU019	Keay 35B	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU020	Sado 1 / Keay 78	Rim	c/ d'en Pujol nº 47	450-535 AD
ILU021	Tipo Tardío B	Rim	c/ Santa Maria nº 10	525-575 AD
ILU022	Keay 62¿A?	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU023	Dressel 23a / Keay 13A	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU024	Dressel 23c / Keay 13C	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU025	Almagro 51A-B / Keay 19A-B	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU026	Almagro 51A-B / Keay 19A-B	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU027	Almagro 51A-B / Keay 19C	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU028	Almagro 51C / Keay 23	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU029	Keay 16A or Almagro 50	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU030	LRA 2	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU031	Indeterminate	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU032	Keay 68/91	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU033	Keay 24A	Rim	c/ Sant Cristòfol nº 12	475-535 AD
ILU034	Keay 62A	Neck	c/ Na Pau	550-575 AD
ILU035	Keay 62A	Body	c/ Na Pau	550-575 AD
ILU036	Keay 62B	Body	c/ Na Pau	550-575 AD
ILU037	Keay 62A	Neck	c/ Na Pau	550-575 AD
ILU038	Keay 62D	Body	c/ Na Pau	550-575 AD
ILU039	Albenga 11-12 / Keay 62Q	Body	c/ Na Pau	550-575 AD
ILU040	Keay 62A	Rim	c/ de la Palma	550-600 (or 550-575) AD
ILU041	African indeterminate	Rim	c/ de la Palma	550-600 (or 550-575) AD
ILU042	Keay 55A	Rim	c/ de la Palma	550-600 (or 550-575) AD
ILU043	Keay 55A	Rim	c/ de la Palma	550-600 (or 550-575) AD
ILU044	Keay 55A	Rim	c/ de la Palma	550-600 (or 550-575) AD
ILU045	Keay 62A	Rim	c/ de la Palma	550-600 (or 550-575) AD
ILU046	Keay 62A	Rim	c/ de la Palma	550-600 (or 550-575) AD
ILU047	Keay 68/91	Rim	c/ Na Pau	550-575 AD
ILU048	LRA 7	Body	c/ d'en Pujol nº 43-45	Late 5th cent.-535 AD
ILU049	African indeterminate	Rim	c/ d'en Pujol nº 51	Late 5th-early 6th cent.
ILU050	Keay 7/25.1	Rim	c/ d'en Pujol nº 51	Late 5th-early 6th cent.
ILU051	Keay 27	Body	c/ Palau nº 32-34	450-500 AD
ILU052	Dressel 23a / Keay 13A	Rim	c/ Palau nº 32-34	450-500 AD

ILU053	Dressel 23 (simile 23a)	Neck	c/ Palau nº 32-34	After 450 AD
ILU054	Keay 24	Rim	c/ Palau nº 32-34	After 450 AD
ILU055	Keay 16A or Almagro 50	Rim	Recolzada del c/ d'en Pujol	Late 5th cent.-535 AD
ILU056	Africana IIA / Keay 4-5	Rim	El Carreró nº 43-45 (Can Ximenes)	Late 3rd-early 4th cent.
ILU057	Keay 16A or Almagro 50	Rim	El Carreró nº 43-45 (Can Ximenes)	Late 3rd-early 4th cent.
ILU058	Keay 16A or Almagro 50	Rim	El Carreró nº 43-45 (Can Ximenes)	Late 3rd-early 4th cent.
ILU059	Keay 1B	Neck	El Carreró nº 43-45 (Can Ximenes)	Late 3rd-early 4th cent.
ILU060	Keay 1B	Neck	El Carreró nº 43-45 (Can Ximenes)	Late 3rd-early 4th cent.
ILU061	Keay 1A	Rim	El Carreró nº 43-45 (Can Ximenes)	Late 3rd-early 4th cent.
ILU062	Keay 36	Rim	c/ Sant Cristòfol nº 12	Late 5th cent.-535 AD
ILU063	Keay 16A or Almagro 50	Rim	c/ Sant Cristòfol nº 12	300-325 AD
ILU064	Africana IIC / Keay 6	Rim	Recolzada del c/ d'en Pujol	Late 5th cent.-535 AD
ILU065	Africana IIA / Keay 4-5	Rim	Recolzada del c/ d'en Pujol	Late 5th cent.-535 AD
ILU066	Keay 1A	Rim	Recolzada del c/ d'en Pujol	Late 5th cent.-535 AD
ILU067	Africana IID / Keay 7	Rim	Recolzada del c/ d'en Pujol	Late 5th cent.-535 AD
ILU068	African indeterminate	Rim	Recolzada del c/ d'en Pujol	Late 5th cent.-535 AD
ILU069	Keay 11 / Tripolitana III	Rim	Recolzada del c/ d'en Pujol	Late 5th cent.-535 AD
ILU070	Almagro 51C / Keay 23	Rim	c/ d'en Pujol nº 51	Late 5th-early 6th cent.
ILU071	Keay 72	Body	El Carreró nº 49	525-575 AD
ILU072	LRA 1B1	Neck	El Carreró nº 49	525-575 AD
ILU073	Keay 55A	Rim	El Carreró nº 49	525-575 AD
ILU074	Keay 57B	Rim	El Carreró nº 49	525-575 AD
ILU075	Keay 62K	Rim	El Carreró nº 49	525-575 AD
ILU076	Keay 62D	Rim	El Carreró nº 49	525-575 AD
ILU077	Keay 72	Rim	c/ Magí de Vilallonga nº 8-12	Mid-/second half of 6th cent.
ILU078	Keay 72	Rim	c/ Magí de Vilallonga nº 8-12	Mid-/second half of 6th cent.
ILU079	LRA 1 (1A transition or 1B1)	Neck	c/ Magí de Vilallonga nº 8-12	Mid-/second half of 6th cent.
ILU080	LRA 1A transition	Body	c/ de la Palma nº 15	550-575 AD
ILU081	LRA 1 (1A transition or 1B1)	Neck	c/ de la Palma nº 15	550-575 AD
ILU082	Keay 55A	Body	c/ de la Palma nº 15	550-575 AD
ILU083	*Spatheion* 2A	Rim	c/ de la Palma nº 15	550-575 AD
ILU084	Almagro 51C / Keay 23	Rim	El Carreró nº 43-45 (Can Ximenes)	Late 5th-early 6th cent.
ILU085	Keay 62A	Rim	c/ de la Palma nº 15	550-575 AD
ILU086	Keay 62A	Rim	c/ de la Palma nº 15	550-575 AD
ILU087	Keay 55B	Rim	c/ de la Palma nº 15	550-575 AD
ILU088	Almagro 51C / Keay 23	Rim	c/ de la Palma nº 15	550-575 AD
ILU089	Keay 62Q	Rim	c/ Santa Maria nº 10	525-575 AD
ILU090	Keay 62Q	Rim	c/ Santa Maria nº 10	525-575 AD
PAL007	Keay 79A	Body	c/ Magí de Vilallonga nº 8-12	Mid-/second half of 6th cent.
PAL008	Keay 72	Body	c/ de la Palma nº 15	550-575 AD
PAL012	Indeterminate	Rim	c/ de la Palma nº 15	550-575 AD
PAL013	Keay 72 nº 5	Rim	c/ de la Palma nº 15	550-575 AD
PAL014	Keay 72 nº 5	Handle	c/ de la Palma nº 15	550-575 AD
PAL060	Indeterminate	Rim	c/ Na Pau	550-575 AD

Table 1. List of the amphora samples analysed, with their typological classification and archaeological information (based on Cerdà et al., 1997; Cela and Revilla, 2004; Revilla, 2011). SU, stratigraphic unit

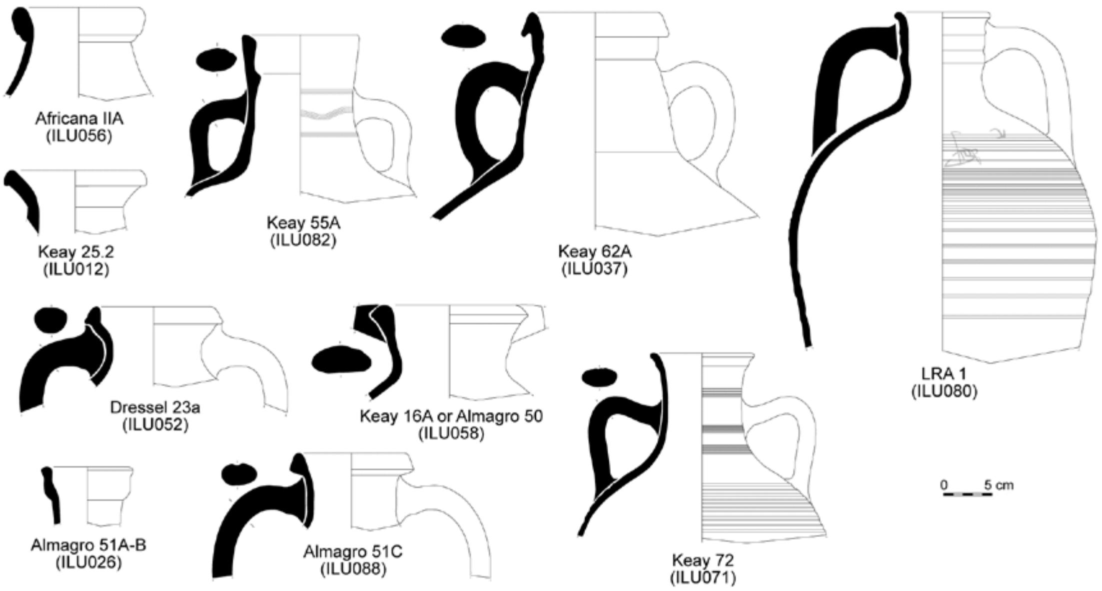

Figure 2. Illustrations of the main amphora types analysed in this study (from Cerdà et al., 1997; Cela and Revilla, 2004)

Each amphora sample was subjected to chemical analysis by means of X-Ray Fluorescence (XRF), mineralogical analysis through X-Ray Diffraction (XRD) and petrographic analysis by means of Optical Microscopy (OM). Two individuals (ILU033 and ILU078) were analysed through OM only, since the small sample size did not allow us to perform the three analyses.

XRF analysis was carried out using a Panalytical-Axios PW 4400/40 spectrometer (see for analytical routine Fantuzzi et al., 2015a). The quantification of the elemental concentrations was obtained by using a calibration line performed with 60 International Geological Standards. The quantified major, minor and trace elements were the following: 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, Th, Nb, Pb, Zr, Y, Sr, Ce, Ga, V, Zn, Cu, Ni and Cr. The compositional data were subjected to multivariate statistical procedures using the software S-PLUS 2000, after an additive log-ratio (alr) transformation of the values obtained by XRF (Aitchison, 1986; Buxeda, 1999).

For the XRD analysis a PANalytical X'Pert PRO MPD alpha 1 diffractometer was used, with Cu–Kα radiation (l = 1.5406 Å), working with spectra from 5 to 80° 2θ, a step-size of 0.026°2θ and a step-time of 47.5 s. For the examination of the crystalline phases the software High Score Plus by PANalytical (including the Joint Committee of Powder Diffraction Standards data bank) was used.

The thin section petrographic analysis was performed using an Olympus BX41 polarising microscope, working with a magnification between 20X and 200X. Each ceramic fabric was described following the system proposed by Whitbread (1989, 1995) and Quinn (2013).

3. RESULTS

3.1. Petrography and mineralogy

The thin-section petrographic analysis of the 96 amphora samples from Mataró reveals a wide diversity of fabrics and fabric groups. We have identified nine fabric groups comprising more than one sample, in addition to 16 fabrics represented by individual samples (see Appendix B). Information on the mineralogical composition of each sample is also provided by the XRD results, which are useful for an estimation of equivalent firing temperatures or EFT (Roberts, 1963; Maggetti, 1982; Cultrone et al., 2001; Buxeda and Cau, 2004; Maggetti et al., 2011) (see Appendix C).

The assemblage is largely dominated by the fabric group ILU-1 (49 samples), characterised by abundant inclusions of quartz (usually rounded-subrounded in the coarser grains) and a variable presence of calcareous inclusions (limestone, calcite and microffosils), quartz arenites and iron nodules. The matrix is iron-rich, although in some cases the presence of streaks of two different clays (ferruginous and calcareous) suggests clay mixing. Based on the relative frequencies of these components and textural characteristics, many different fabrics can be differentiated. Eight of these fabrics (ILU-1.1 to 1.8) are represented by more than one sample (for their main characteristics see Appendix B); the most represented ones are illustrated in Figure 3. In addition, 17 samples (ILU008, 009, 013, 015, 022, 033, 039, 041, 049, 054, 067, 068, 069, 074, 076, 082, 083) can be considered as petrographic loners within this large group. According to the mineralogical phases in the XRD patterns, the EFT for the samples in ILU-1 is usually between 850-950ºC, in many cases with firing phases derived from a calcareous composition (gehlenite, plagioclase, pyroxene). However, there are many exceptions, with low-fired (≤850ºC) or high-fired (≥950/1000ºC) samples (Appendix C). The mineral phases reveal a lower calcareous composition for the fabric ILU-1.2 than for the other fabrics in this group.

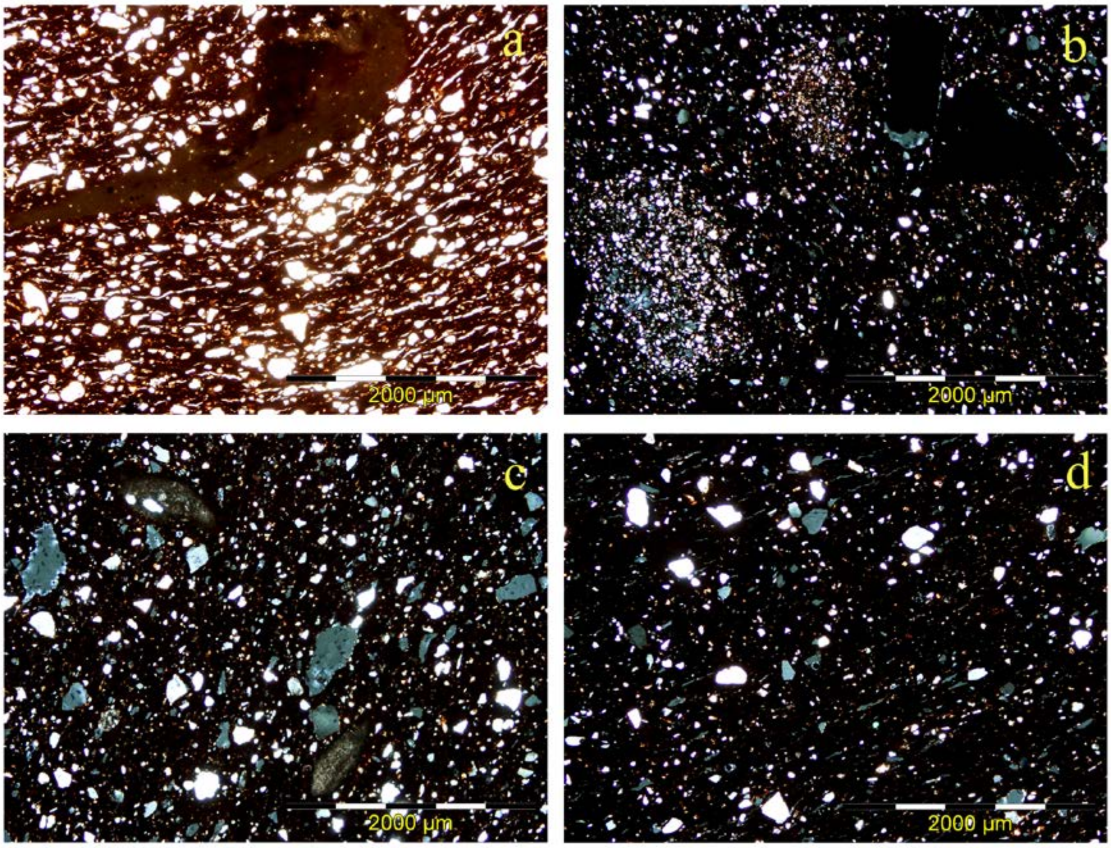

Figure 3. Microphotographs of thin sections from the petrographic fabric group ILU-1, all taken at the same magnification (40x) under plane polarised light (a) or crossed polars (b-d). (a) ILU-1.1: sample ILU051. (b) ILU-1.2: sample ILU087. (c) ILU-1.3: sample ILU040. (d) ILU-1.5: sample ILU036

The rest of the fabrics or fabric groups in the analysed assemblage are less represented, with many different petrographic compositions being documented (Figure 4; see description of each fabric in Appendix B; for the mineral phases identified through XRD and the estimated EFT for each sample, see Appendix C). Apart from ILU-1, four fabrics present a predominant sedimentary composition (ILU-2, 3, 4 and 5; Figure 4a-b), two of them (ILU-4 and 5) with a micaceous matrix. ILU-4, with very fine-textured fabrics, is a well represented group in the assemblage (Figure 4b). Another well represented fabric group is ILU-6 (Figure 4c), with a metamorphic component subordinated to the dominant sedimentary inclusions. Also in some other fabrics (ILU-7, 8 and 9) subordinated metamorphic inclusions are found, but with a more micaceous matrix in each case. Three fabrics (ILU-10, 11 and 12) show dominant sedimentary inclusions and an accessory igneous contribution, while another two fabrics (ILU-13 and 14) present also a minor metamorphic contribution; of these, ILU-13 (Figure 4d) is the best represented one, with six individuals belonging actually to three different fabrics in the same group.

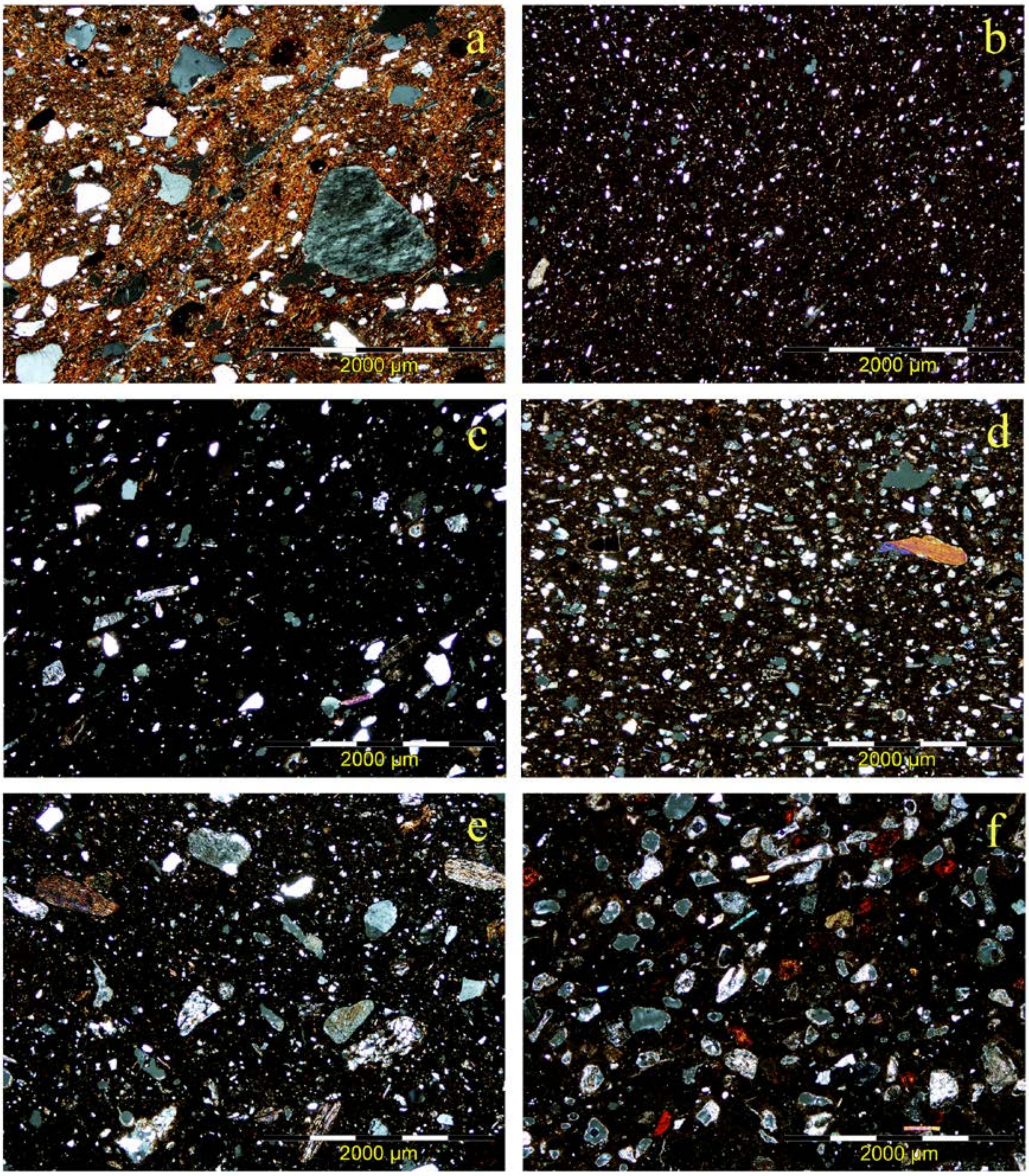

Figure 4. Microphotographs of thin sections from various petrographic fabrics, all taken under crossed polars at the same magnification (40x). (a) ILU-3.2: sample ILU020. (b) ILU-4.1: sample ILU078. (c) ILU-6.1: sample ILU052. (d) ILU-13.1: sample ILU063. (e) ILU-15.1: sample ILU053. (f) ILU-23.1: sample ILU072

Some fabrics are characterised, instead, by predominant metamorphic inclusions (ILU-18, 19, 20, 21 and 22). In the group ILU-15 (Figure 4e), subordinated sedimentary inclusions and an eventual accessory ophiolitic contribution are present, in fabrics dominated by metamorphic rock fragments. The fabrics ILU-16 and ILU-17 contain mainly metamorphic and sedimentary inclusions, along with a minor igneous contribution.

Igneous and sedimentary inclusions are frequent in the fabrics ILU-24 and ILU-25, the latter also with abundant metamorphic rock fragments. A quite distinctive fabric group is ILU-23 (Figure 4f), with dominant ophiolitic and calcareous inclusions; a certain diversity of fabrics is observed in the four samples of this group (Appendix B).

3.2. Chemical results

The normalised XRF chemical results (Appendix D) show a significant compositional heterogeneity in the data set. This can be first explored through the calculation of the variation matrix (Aitchison, 1986, 1992; Buxeda and Kilikoglou, 2003), in which the obtained total variation value (*vt*= 2.72) is indicative of a polygenic population. According to the variation matrix, the most variable elements in the data set are CaO ($\tau._{CaO}$= 16.71), Pb ($\tau._{Pb}$= 7.92), Na_2O ($\tau._{Na2O}$= 7.52), Cu ($\tau._{Cu}$= 7.36), Ni ($\tau._{Ni}$= 7.05), P_2O_5 ($\tau._{P2O5}$= 6.49), Sr ($\tau._{Sr}$= 6.42) and Cr ($\tau._{Cr}$= 6.39), even if other elements present high $\tau._i$ values as well. The variations in some of these elements, in particular Pb and P_2O_5, should be taken with caution, since these can be often associated with possible contamination processes. The high variance for Pb ($\tau._{Pb}$) is clearly influenced by three samples (ILU029, ILU064 and PAL014: Appendix D) enriched in this element; however the petrographic-mineralogical analysis does not show any particularity that could help to explain this enrichment and, in fact, other samples with a similar fabric to that of ILU029 (ILU-13.1) and ILU064 (ILU-1.6) do not present such high concentrations.

The high variability introduced by CaO and Sr is due to the presence of samples from very calcareous (CaO>20% in four samples) to very low calcareous (CaO<2% in six samples) (Appendix D). There are five individuals (ILU030, 072, 079, 080, 081) that can be clearly separated from the remaining samples according to their very high concentrations of Ni and Cr, along with a high content of CaO and MgO and low of SiO_2 and Zr. This first division of the data set can be better observed in the PCA in Figure 5, performed on the subcomposition Fe_2O_3, Al_2O_3, MnO, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2, Ba, Rb, Th, Nb, Zr, Y, Sr, Ce, Ga, V, Zn, Cu, Ni and Cr, after an additive log ratio (alr) transformation of the concentrations; Fe_2O_3 was used as a divisor (P_2O_5 and Pb were not included in this analysis due to possible contamination problems). Three general chemical groups (A, B, C) can be differentiated in the biplot PC1-PC2 (Figure 5; Table 2). The first one (A) comprises very low calcareous samples

(CaO<1.5%, Sr<200ppm), that are related to fabrics with iron-rich matrix and very few (ILU-22) or no calcareous inclusions (ILU-3, ILU-9). The second group (B) is composed of samples characterised by high Ni, Cr, CaO and MgO, among other particularities (Table 2); this group is associated with fabrics showing both a Ca-rich clay matrix and abundant calcareous inclusions (ILU-2, ILU-23), while the enrichment of Ni, Cr and MgO is clearly related, in ILU-23, to the presence of ophiolitic inclusions, derived from ultramafic and mafic igneous rocks. The general group C in the PCA comprises the rest of the samples in the data set, except for the sample ILU048 that behaves as a chemical loner (Figure 5).

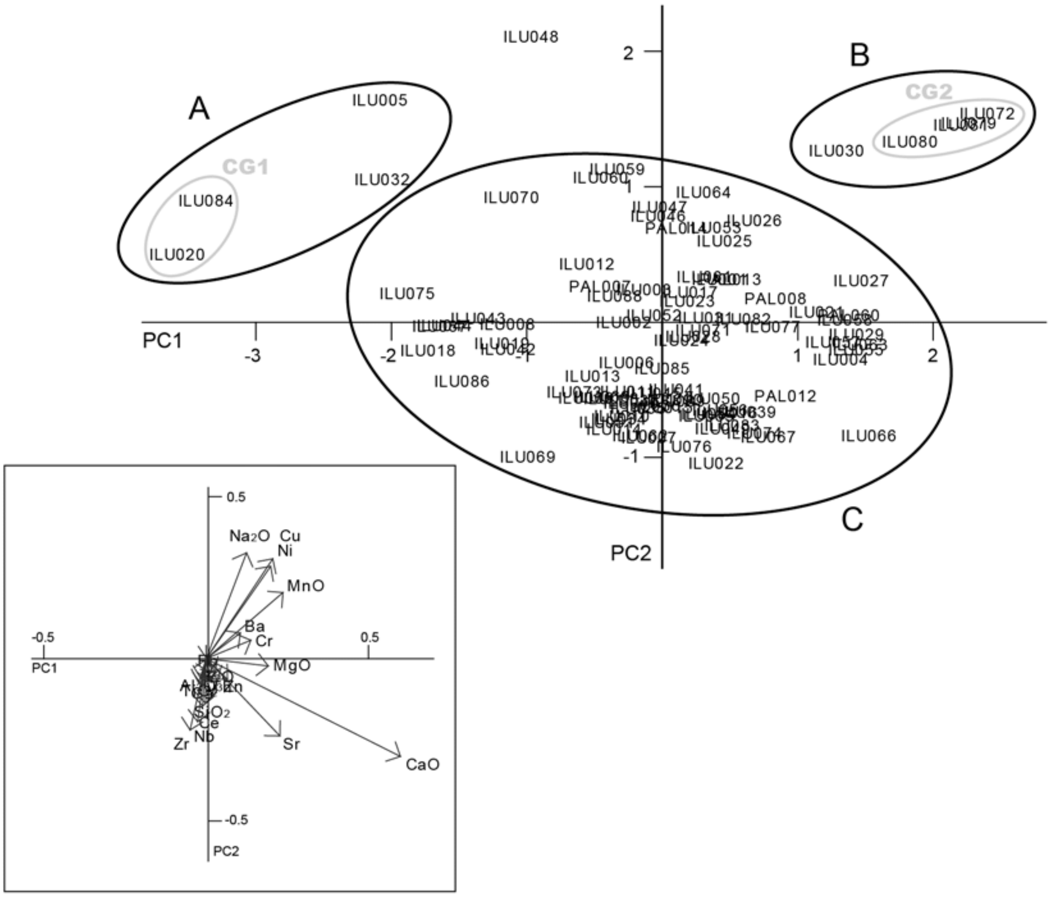

Figure 5. PCA of the alr-transformed chemical data for the 94 samples analysed through XRF. Plot PC1-PC2, based on the subcomposition Al_2O_3, MnO, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2, Ba, Rb, Th, Nb, Zr, Y, Sr, Ce, Ga, V, Zn, Cu, Ni and Cr (Fe_2O_3 is used as a divisor in the log-ratio transformation). PC1 accounts for 62% of the total variance, while PC2 explains 17% of the variation. The analysis was performed on the covariance matrix. CG: chemical group

Besides this first general division of the data set, closer similarities in chemical composition between a series of samples allow for the differentiation of better-defined chemical groups (CG). From the chemical data (Appendix D) and the PCA in Figure 5, a strong chemical relation is seen between the samples ILU020 and ILU084 (CG1), on one hand, and between ILU072, ILU079, ILU080 and ILU081 (CG2), on the other hand; these CG correspond to fabric groups ILU-3 and ILU-23, respectively. The samples ILU005, ILU030 and ILU032 may be considered as chemical loners.

As for the remaining samples in the data set, the chemical similarities can be better explored though a cluster analysis (Figure 6), based on the same subcomposition as in the PCA of Figure 5, but in this case using Y as a divisor for the alr transformation of the concentrations. The analysis reveals the presence of six chemical groups (CG3 to CG8) and a series of loners. Both the cluster tree and the normalised chemical data indicate that even within these groups a certain compositional variability can be found, but some samples show, in any case, stronger similarities that allow for the definition of chemical subgroups (Figure 6). The mean chemical composition of each group and subgroup is given in Table 3.

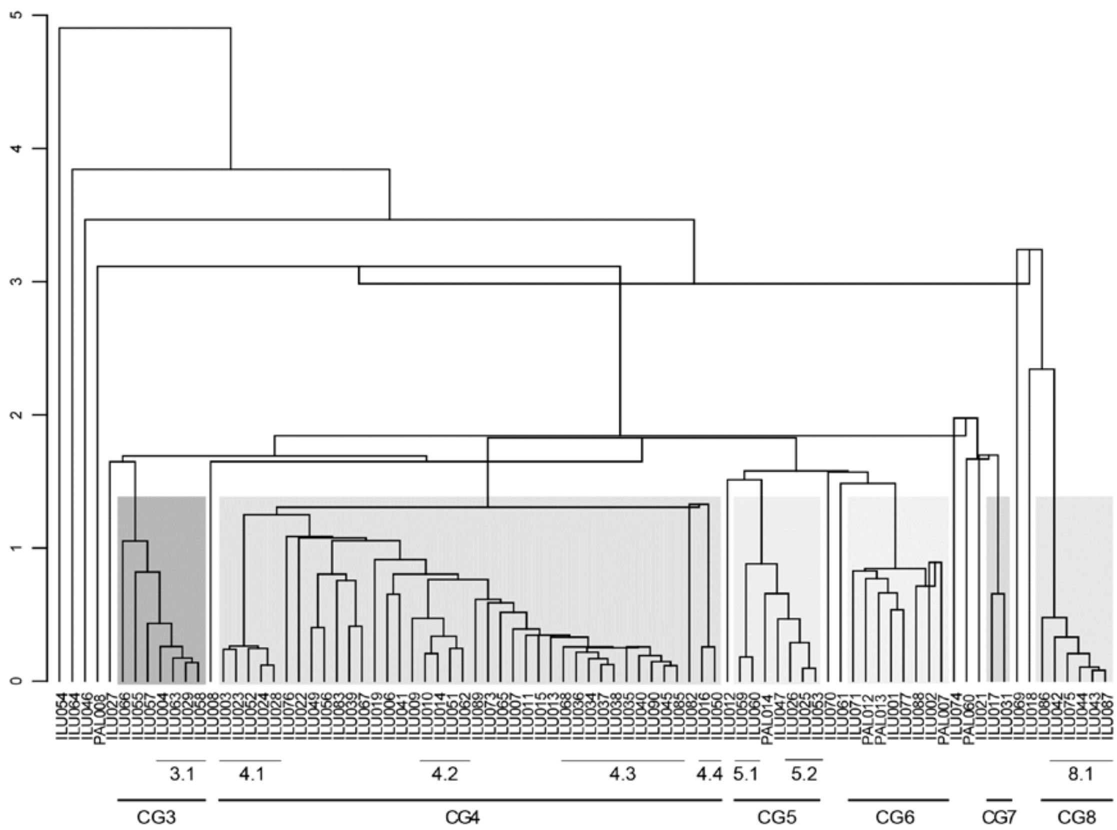

Figure 6. Dendrogram resulting from a cluster analysis (using the centroid agglomerative method and the squared Euclidean distance) on 84 samples, based on the subcomposition Fe_2O_3, Al_2O_3, MnO, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2, Ba, Rb, Th, Nb, Zr, Sr, Ce, Ga, V, Zn, Cu, Ni and Cr; Y was used as a divisor in the log-ratio transformation of the data. CG: chemical group

		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*	*Cr*
A (n=4)																										
	m	6,27	17,70	0,04	0,10	0,87	1,14	0,91	0,89	2,96	68,96	474	136	15	15	30	230	33	93	71	21	101	59	14	27	80
	sd	1,91	3,65	0,05	0,05	0,16	0,37	0,47	0,56	0,62	6,27	119	36	4	3	9	32	10	52	26	4	26	13	10	13	28
B (n=5)																										
	m	6,19	12,16	0,10	0,43	0,61	4,45	23,49	1,21	2,09	49,07	496	75	13	11	18	128	23	389	54	14	104	80	28	202	497
	sd	0,55	2,14	0,02	0,16	0,08	0,58	3,40	0,44	0,44	1,75	80	18	2	3	9	30	5	118	17	2	6	9	7	39	246
C (n=84)																										
	m	5,55	14,65	0,05	0,30	0,75	2,22	10,78	0,54	2,65	62,37	443	93	13	16	27	222	25	290	70	18	107	87	18	30	102
	sd	0,75	2,26	0,02	0,12	0,09	0,72	4,79	0,24	0,70	4,40	165	32	2	3	23	45	3	94	9	3	19	19	10	7	20
Loner ILU048		11,18	16,18	0,16	0,48	1,99	3,10	4,35	1,74	2,20	58,44	552	49	9	21	11	242	34	283	65	21	192	108	68	79	157

Table 2. Mean chemical composition of the general groups (A, B, C) defined from the PCA in Figure 5. Mean (m) and standard deviation (sd) values are presented for each element

		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*	*Cr*
CG1 (n=2)	m	5,51	17,72	0,01	0,13	0,76	0,89	0,53	0,44	3,34	70,54	526	158	15	13	31	203	29	59	59	22	87	55	10	19	64
	sd	0,23	0,88	0,00	0,07	0,09	0,16	0,11	0,18	0,32	0,56	10	33	0	1	8	16	5	2	5	0	9	3	4	6	2
CG2 (n=4)	m	5,98	11,23	0,09	0,48	0,58	4,63	24,71	1,38	2,03	48,67	488	68	12	10	15	116	20	437	47	13	104	76	27	187	550
	sd	0,35	0,53	0,01	0,12	0,06	0,47	2,35	0,23	0,48	1,75	90	10	1	1	6	11	1	58	2	1	6	6	7	22	250
CG3 (n=7)	m	4,37	11,53	0,06	0,40	0,65	3,31	18,80	0,46	2,97	57,31	492	88	12	12	40	215	25	291	59	15	81	73	24	25	72
	sd	0,29	1,04	0,01	0,14	0,07	1,13	0,54	0,10	0,52	1,15	63	15	2	2	35	5	1	32	4	2	8	11	4	3	6
Subgroup CG3.1 (n=4)	m	4,46	11,41	0,06	0,46	0,63	2,83	18,62	0,53	2,96	57,87	489	91	12	12	49	218	25	306	61	15	85	72	27	26	75
	sd	0,17	0,27	0,01	0,17	0,01	0,27	0,51	0,04	0,28	0,49	74	2	1	0	46	5	1	27	2	0	4	5	2	2	3
CG4 (n=40)	m	5,52	14,08	0,04	0,26	0,75	2,17	11,04	0,43	2,25	63,31	356	77	12	17	19	229	24	309	72	18	112	82	12	28	111
	sd	0,58	1,37	0,01	0,08	0,07	0,52	3,08	0,14	0,36	3,11	103	12	1	2	4	35	2	84	8	2	19	12	3	4	12

Subgroup CG4.1 (n=5)	m	6,38	15,72	0,06	0,30	0,80	2,61	11,79	0,55	2,53	59,11	330	98	12	15	24	175	23	289	68	20	148	92	17	36	125
	sd	0,20	0,62	0,01	0,02	0,03	0,24	2,00	0,03	0,15	1,62	45	6	1	1	7	3	1	16	6	1	7	5	3	4	6
Subgroup CG4.2 (n=4)	m	5,52	14,23	0,04	0,16	0,78	1,38	9,79	0,24	1,74	65,97	258	70	12	17	17	238	24	342	72	18	103	77	13	26	121
	sd	0,41	0,74	0,00	0,01	0,03	0,11	1,26	0,05	0,10	2,17	24	1	0	1	1	12	1	56	5	1	7	7	2	2	6
Subgroup CG4.3 (n=10)	m	5,66	14,80	0,04	0,27	0,80	2,60	9,80	0,48	2,46	62,95	321	81	12	19	18	254	26	272	78	18	115	86	11	28	114
	sd	0,34	0,88	0,00	0,08	0,03	0,25	1,01	0,09	0,12	1,88	62	6	1	1	2	24	1	30	5	1	10	6	2	2	8
Subgroup CG4.4 (n=2)	m	5,12	13,27	0,05	0,29	0,71	1,42	13,39	0,25	1,63	63,70	554	64	12	15	18	215	23	417	68	17	83	73	16	24	117
	sd	0,17	1,07	0,00	0,06	0,04	0,06	1,75	0,01	0,03	3,01	37	2	0	1	2	21	0	97	1	1	6	1	1	1	3
CG5 (n=7)	m	6,23	15,53	0,08	0,41	0,77	2,35	8,19	0,86	2,96	62,46	543	112	13	15	43	192	27	234	67	19	113	95	31	42	100
	sd	0,41	1,86	0,01	0,07	0,06	0,44	2,98	0,15	0,41	4,53	106	18	2	2	25	14	3	68	6	3	9	10	4	4	7
Subgroup CG5.1 (n=2)	m	6,01	14,42	0,07	0,45	0,75	1,76	4,64	0,82	2,53	68,39	591	97	12	13	55	192	24	159	63	18	116	90	32	37	108
	sd	0,45	1,36	0,01	0,02	0,08	0,15	0,53	0,03	0,32	2,86	34	9	1	1	6	8	2	16	1	1	13	10	8	4	1
Subgroup CG5.2 (n=3)	m	6,07	14,79	0,08	0,39	0,73	2,59	11,10	0,84	3,03	60,22	476	112	14	14	25	182	27	256	64	18	110	90	31	43	94
	sd	0,27	0,66	0,01	0,10	0,04	0,06	0,65	0,05	0,08	0,62	52	8	1	1	4	12	2	12	5	1	8	1	3	1	6
CG6 (n=8)	m	5,50	18,04	0,04	0,40	0,81	1,76	10,96	0,53	3,55	58,23	653	158	17	17	32	212	31	220	72	22	97	94	25	36	88
	sd	0,70	2,12	0,01	0,16	0,11	0,27	4,22	0,12	0,49	2,77	117	36	2	3	9	27	2	40	11	3	17	17	4	6	14
CG7 (n=2)	m	6,01	14,04	0,04	0,37	0,65	1,57	13,84	0,68	2,71	59,91	720	61	10	13	43	165	20	277	63	17	107	139	18	29	111
	sd	0,47	0,73	0,00	0,03	0,05	0,00	0,35	0,08	0,74	2,49	323	2	0	0	2	15	0	16	1	1	10	0	2	0	1
CG8 (n=6)	m	5,97	15,26	0,03	0,17	0,87	2,23	2,15	0,50	2,93	69,73	341	97	13	19	20	307	27	312	78	19	112	87	12	28	107
	sd	0,15	0,38	0,00	0,02	0,02	0,07	0,59	0,03	0,09	0,66	15	5	1	1	1	23	1	83	1	1	5	2	1	3	7
Subgroup CG8.1 (n=5)	m	5,97	15,19	0,03	0,17	0,86	2,21	2,14	0,50	2,93	69,85	341	96	13	19	20	303	27	280	78	19	110	87	12	28	106
	sd	0,17	0,37	0,00	0,02	0,02	0,06	0,66	0,03	0,10	0,67	17	4	1	1	1	23	1	26	1	0	5	2	1	3	8

Table 3. Mean chemical composition of the groups CG1 to CG8 and the various chemical subgroups defined from the cluster analysis. Mean (m) and standard deviation (sd) values are presented for each element

The chemical group CG3 is characterised by a high calcareous content (CaO 18.1-19.6%) —even if the levels of Sr are not higher than in other groups— along with low concentrations of Al_2O_3 and Cr; this CG correspond to fabrics with calcareous matrix and inclusions, in particular the fabric group ILU-13. Conversely, the samples in CG8, which are associated with the fabric ILU-1.2 mainly, are low calcareous (CaO 1.4-3.2%), but the Sr concentrations are not lower than in other groups; they are differentiated also by the high content of SiO_2 and Zr (Table 3; Appendix D). This composition is related to the almost absence of calcareous inclusions and the very high frequency of fine quartz grains observed in thin section.

Both the chemical groups CG5 and CG6 comprise calcareous individuals. Despite their differentiation in the cluster analysis, both are quite heterogeneous groups actually, as can be inferred from the cluster tree (Figure 6) and the examination of the chemical data (*e.g.* the high standard deviation values for elements such as CaO and Al_2O_3, see Table 3 and Appendix D). This variability is higher in CG6, where the samples share as a common feature high concentrations of Al_2O_3, K_2O and Rb; this chemical group is associated with a variety of muscovite-rich fabrics (ILU-4, ILU-5, ILU-7, ILU-12, ILU-21), what can explain such chemical concentrations as well as the compositional heterogeneity observed in CG6. With regard to CG5, two chemical subgroups (CG5.1 and 5.2), each with a certain compositional homogeneity (Table 3; Appendix D), can be differentiated; these subgroups correspond well with the petrographic fabric groups ILU-16 and ILU-15, respectively.

The largest chemical group from the cluster analysis is CG4, with 40 samples that in all the cases correspond to calcareous ceramics, however with quite variable CaO percentages (4.5-19.0%). This is, again, a somewhat heterogeneous group in which a few subgroups (CG4.1 to 4.4) with more homogeneous compositions can be differentiated (Figure 6; Table 3). The most represented is CG4.3 (n=10), with a very low total variation (*vt*= 0.17), indicative of a monogenic sample. The other subgroups are less represented ($n \leq 5$). The most distinctive of these subgroups is CG4.1, with the highest levels of V in the data set; when compared to the other samples in CG4, it shows a higher content of Fe_2O_3 and Rb and lower of SiO_2 and Zr (Table 3). The samples in this chemical subgroup belong to the fabric group ILU-6, while the rest of the samples in CG4 are related to the fabric groups ILU-1 and ILU-10. The wide variety of petrographic fabrics in ILU-1 is consistent with the variability of chemical compositions found in the group CG4.

Finally, two samples (ILU017, 031) form a small group (CG7) with a calcareous composition (CaO 13.6-14.1%), high levels of Zn and low of MgO and Rb (Figure 6; Table 3). These samples show the same petrographic fabric (ILU-1.6); when compared to the rest of fabrics in the petrographic group ILU-1, the type of inclusions observed in thin section (quartz, calcite, microfossils, iron nodules) accounts for the high CaO percentage, but does not allow for a clear interpretation of the other chemical particularities mentioned.

4. DISCUSSION

The integration of the chemical results with the petrographic-mineralogical evidence sheds more light on the compositional variability of the analysed assemblage and enables to obtain a better characterisation of each fabric. The provenance of these fabrics was investigated, based on a comparison with reference materials, the available published information on similar fabrics and the geological background of the presumable production areas/centres, also taking into account the archaeological evidence in each case. This allowed us to distinguish fabrics from *Africa*, *Hispania* (especially from the *Baetica*) and, in a few cases, the eastern Mediterranean (Table 4). A significant compositional heterogeneity was found in each case, with many fabrics represented by individual samples. We will focus this discussion on the most represented fabrics only.

Fabric	*Samples*	*CG*	*Amphora type/s*	*Provenance hypothesis*
ILU-1.1	ILU010, 051, 062. Rel.: ILU014, 016, 050	CG4.2, 4.4	Keay 27, Keay 36, *Spatheion* 1 or Keay 25, Keay 7/25.1	NW Tunisia?
ILU-1.2	ILU019, 042, 043, 044, 073, 086, 087	CG8, CG4	Keay 55 (var. A and B), Keay 35B, Keay 62A	N Tunisia: Nabeul zone B (Sidi Zahruni)
ILU-1.3	ILU035, 040, 045, 085	CG4.3	Keay 62A	Tunisia (Nabeul? Sahel?)
ILU-1.4	ILU089, 090	CG4	Keay 62Q	Tunisia (Nabeul? Other possibilities not excluded)
ILU-1.5	ILU036, 037, 038. Rel.: ILU034	CG4.3	Keay 62 (var. A, B, D)	C Tunisia (Sahel): Henchir ech Chekaf
ILU-1.6	ILU017, 031. Rel.: ILU064	CG7, loner	Keay 27A or 7/25.1, indeterminate, Africana IIC	Tunisia
ILU-1.7	ILU018, 075. Rel.: ILU006, 012	CG4, CG8, loners	Keay 35B, Keay 62K, Africana IIA, Keay 25.2	Tunisia (Nabeul zone B not excluded)
ILU-1.8	ILU007, 011	CG4	Keay 25.1, indeterminate	Tunisia
ILU-1 (loners)	ILU008, 009, 013, 015, 022, 033, 039, 041, 049, 054, 067,	CG4, loners	Africana IID, Keay 11/Tripolitana III, Keay 25.1, Keay 25.2, *Spatheion*	Tunisia (Algeria not excluded for ILU033 and ILU054)

	068, 069, 074, 076, 082, 083		2A, Keay 24, Albenga 11-12, Keay 55A, Keay 57B, Keay 62 (var. A and D), indeterminate	
ILU-2	ILU030	Loner	LRA 2	Argolis (possibly Kounoupi), other possibilities not excluded
ILU-3.1	ILU084	CG1	Almagro 51C/Keay 23	W *Lusitania*: Tagus/Sado valleys
ILU-3.2	ILU020	CG1	Sado 1/Keay 78	W *Lusitania*: Sado valley
ILU-4.1	ILU071, 078, PAL007	CG6	Keay 72, Keay 79A	*Balearica* (Eivissa most probably)
ILU-4.2	ILU066, 077, PAL008, 012	CG6, CG3, loner	Keay 72, indet., PE-25 (residual)	*Balearica* (Eivissa most probably)
ILU-5	ILU002	CG6	Indeterminate	Indeterminate (*Balearica*? *Baetica*? others?)
ILU-6.1	ILU023, 052	CG4.1	Dressel 23a	*Baetica:* Guadalquivir/Genil valleys
ILU-6.2	ILU003	CG4.1	Dressel 23¿c?/simile Tejarillo II	*Baetica:* Guadalquivir/Genil valleys
ILU-6.3	ILU024, 028	CG4.1	Dressel 23c; Dressel 23a or Tejarillo III	*Baetica:* Guadalquivir/Genil valleys
ILU-7	ILU001	CG6	Indeterminate (¿Dressel 23a?)	*Baetica:* Guadalquivir/Genil? Other possibilities not excluded
ILU-8	PAL014	CG5	Keay 72 nº 5	Indeterminate (*Baetica*? Eastern *Tarraconensis*?)
ILU-9	ILU032	Loner	Almagro 51A-B/Keay 19C	W *Lusitania*: Tagus/Sado valleys
ILU-10	ILU056, 065	CG4	Africana IIA	C Tunisia (Sahel): *Sullecthum*
ILU-11	ILU048	Loner	LRA 7	*Aegyptus*: middle Nile valley
ILU-12	PAL013	CG6	Keay 72 nº 5	Eastern *Tarraconensis* (central or northern Catalan coast)
ILU-13.1	ILU004, 029, 058, 063	CG3.1	Keay 16A or Almagro 50	S *Hispania* (Baetican coast?)
ILU-13.2	ILU055	CG3	Keay 16A or Almagro 50	S *Hispania* (Baetican coast?)
ILU-13.3	ILU057	CG3	Keay 16A or Almagro 50	S *Hispania* (Baetican coast?)
ILU-14	PAL060	Loner	Indeterminate	S *Hispania* probably (Baetican coast?)
ILU-15.1	ILU025, 053	CG5.2	Almagro 51A-B/Keay 19A-B, Dressel 23	*Baetica:* western coast of Málaga
ILU-15.2	ILU026	CG5.2	Almagro 51A-B/Keay 19A-B	*Baetica:* western coast of Málaga
ILU-16	ILU059, 060	CG5.1	Keay 1B	Algeria possibly
ILU-17	ILU061	Loner	Indeterminate	*Baetica:* Guadalquivir/Genil? Other possibilities not excluded
ILU-18	ILU047	CG5	Indeterminate	Coast of *Baetica* between Málaga and Granada
ILU-19	ILU027	Loner	Almagro 51A-B/Keay 19C	Coast of *Baetica* (possibly Málaga region)
ILU-20	ILU070	Loner	Almagro 51C/Keay 23	Coast of *Baetica* or *Carthaginensis*
ILU-21	ILU088	CG6	Almagro 51C/Keay 23	Coast of *Baetica* or *Carthaginensis*
ILU-22	ILU005	Loner	Beltrán IIB (residual)	Coast of *Baetica* between Granada and Málaga
ILU-23.1	ILU072, 081	CG2	LRA 1 (var. 1B1/Kellia 164 and 1A transition?)	*Oriens*: probably *Cilicia*/northern *Syria*
ILU-23.2	ILU079	CG2	LRA 1 (1A transition or 1B1)	*Oriens*: probably *Cilicia*/northern *Syria*
ILU-23.3	ILU080	CG2	LRA 1A transition	*Oriens*: *Cilicia*/northern *Syria*
ILU-24	ILU021	Loner	Tipo Tardío B	Eastern *Tarraconensis* (central or northern Catalan coast)
ILU-25	ILU046	Loner	Indeterminate	Eastern *Tarraconensis* (central or northern Catalan coast)

Table 4. Summary of the results obtained, organised by fabric. CG: chemical group. Typology for a few samples differs from Table 1 since the analysis allowed for their typological reclassification

4.1. African fabrics

The large fabric group ILU-1 (49 samples) can be clearly related to the Tunisian Fabric defined by Capelli (2005a, 2005b); the typological evidence is consistent with this general provenance in all the cases. Also the fabric group ILU-10 (2 samples of Africana IIA amphorae), with an accessory igneous contribution, must be associated with a Tunisian provenance, since it is a typical fabric of the *Sullecthum* workshops in central-eastern Tunisia (Capelli et al., 2006). Concerning the fabrics in the group ILU-1, a more precise provenance hypothesis was possible for many of them, thanks to the comparison with published studies on the petrographic characterisation of some workshops (*e.g.* Capelli, 2005a, 2005b, 2007; Ghalia et al., 2005; Capelli et al., 2006; Capelli and Bonifay, 2007, 2014; Bonifay et al., 2010, 2011) and with the fabric reference collection for Tunisian workshops of the University of Genova. Due to the large number of these fabrics —in many cases represented by one sample only— a detailed discussion on the Tunisian amphora assemblage will not be possible here but will be object of a specific study to be published elsewhere. In the present discussion we provide just a brief summary for the most represented fabrics (ILU-1.1 to 1.8).

The Tunisian amphorae correspond, in the chemical analysis, to the chemical groups CG4 (except the subgroup CG4.1), CG7 and CG8, in addition to a series of loners. The fabric ILU-1.1 and some related samples (Appendix B; Table 4) form the chemical subgroups CG4.2 and CG4.4. A similar fabric has been reported in amphorae of similar types (*e.g.* Keay 27 and 36) from other contexts and a probable provenance in northwestern Tunisia has been suggested (Bonifay, 2004; Bonifay et al., 2011; Fantuzzi et al., 2015a, 2015b). In any case, the chemical and petrographic variability suggests that more than one workshop or paste recipe may have existed.

The fabric ILU-1.2, well represented in our study, is quite characteristic of the Sidi Zahruni workshop in Nabeul zone B, in northeastern Tunisian (Bonifay, 2004; Capelli, 2005a, 2005b; Ghalia et al., 2005; Bonifay et al., 2010). The seven samples (Table 4) are related to types whose production has been documented in this workshop (Keay 55, Keay 35B and Keay 62A). They belong to the chemical group CG8 mainly (low calcareous), except for two chemical loners in CG4 (ILU019, ILU073) that are similar in composition but with differences in a few elements (in particular CaO and Sr). Their fabric is very similar anyway and they seem to come from the same workshop.

For the fabric ILU-1.5 a provenance in the workshop of Henchir ech Chekaf, in central-eastern Tunisia, can be proposed, based on its clear correspondence with the fabric reference groups from this centre (Capelli, 2005a, 2005b, 2007); the typology of the four samples (Keay 62 amphorae: Table 4) is also consistent with this interpretation. They correspond to a same chemical subgroup (CG4.3), with more similarities between them than with other samples of the same subgroup, as can be seen in Figure 6.

The rest of the main fabrics in ILU-1 could not be associated clearly with any known fabric from Tunisian workshops, but partial fabric similarities, along with the chemical evidence and the integration of the archaeological information, allow us to provide possible provenance hypothesis in some cases. The fabrics ILU-1.3 and ILU-1.4 show fabric similarities with the products from Nabeul zone B (especially ILU-1.4 for the abundance of sandstone with a carbonate cement), but the chemical composition (CG4.3, except for the loner ILU089) is more similar to the fabric from Henchir ech Chekaf (Figure 6; Appendix B), so we cannot exclude an hypothetical provenance in the Sahel area as well. For ILU-1.3 the typological evidence (Keay 62A amphorae) would favour this last hypothesis (see Bonifay, 2004), but for ILU-1.4 (Keay 62Q type) both the Nabeul and Sahel areas could be compatible (Bonifay, 2004; Bonifay et al., 2011; Capelli and Bonifay, 2014). Due to these problems, further archaeometric and archaeological evidence from production centres is needed in order to get a more reliable interpretation of the provenance of these fabrics.

A similar situation is observed for the fabric ILU-1.7, for which the archaeological/typological evidence of the samples (Africana IIA, Keay 25.2, Keay 35B and Keay 62 amphorae) would suggest a possible association with Nabeul zone B (Bonifay, 2004; Ghalia et al., 2005; Bonifay et al., 2010), but the fabric documented in Mataró has not been reported so far in this production area. For the samples ILU018 and, especially, ILU075, the chemical evidence indicate compositional similarities (CG8) with the fabric ILU-1.2, coming from Nabeul zone B (Figure 6). However, it seems preferable to wait for further petrographic evidence from the workshops for a stronger provenance interpretation.

Apart from ILU-1 and ILU-10, another possible African fabric is ILU-16, that comprises two samples (ILU059, 060) of the type Keay 1B with a similar chemical composition (CG5.1). A similar fabric has been documented in other amphorae of the same type and the archaeometric and archaeological evidence points to a possible provenance in Algeria, though not excluding other possibilities (see discussion in Capelli and Bonifay, 2007).

4.2. Hispanic fabrics

Five fabric groups (ILU-3, ILU-4, ILU-6, ILU-13, ILU-15) that are represented by more than one sample in this study can be related to a Hispanic provenance (Table 4).

The fabric group ILU-3 is the only of these that is characterised by a low calcareous composition (CG1). A provenance in western Lusitania (lower Tagus/Sado valleys) can be proposed for this fabric, based on the comparison with similar chemical-petrographic fabrics from this area (*e.g.* Mayet et al., 1996; Fantuzzi et al., 2015a). The typological evidence (Almagro 51C and Sado 1 types) is in agreement with this interpretation. It is a fabric rich in quartz and phyllosilicates, what can be related to the high concentrations of SiO_2, Al_2O_3, K_2O and Rb (Table 3).

The five samples in the petrographic group ILU-6 are similar in chemical composition (CG4.1); they belong to the amphora type Dressel 23 (variants 23a and 23c) mainly. A similar fabric and chemical composition has been documented in other contexts for samples of the same type, and a provenance in the Guadalquivir/Genil valleys seems the most plausible hypothesis based on archaeometric and archaeological information (see discussion in Fantuzzi et al., 2015a, 2015b). The three different fabrics defined in the present study seem to suggest that more than one workshop or paste recipe could be represented, although further archaeometric investigation is needed from the consumption centres for a better understanding of this compositional diversity.

Another Baetican fabric group is ILU-15, which is also homogeneous in chemical composition (CG5.2). The petrographic characteristics point to a provenance in the western coast of Málaga, located near outcrops of the Maláguide complex (sedimentary and very low-grade metamorphic rocks) and the Alpujarride complex (higher-grade metamorphic rocks and peridotites). This is consistent with the archaeological information, since this fabric comprises amphorae of types Almagro 51A-B and Dressel 23, whose production has been attested in some workshops in this area (Bernal, 2001).

The fabric group ILU-13 comprises six samples that are included in the same chemical group (CG3), characterised by a high calcareous composition. All the samples belong to the type Keay 16A or Almagro 50, a quite characteristic southern Hispanic amphora (Keay, 1984; Bernal, 2001). Four of these samples show the same fabric (ILU-13.1) and present a more homogeneous chemical composition (GQ3.1) when compared to the other samples. A similar fabric was described by Peacock and Williams (1986) for the Almagro 50 type, these authors suggesting a possible provenance in the Algarve region on the basis of the petrographic composition; however, this fabric has not been described at any Algarvian workshop so far (see Mayet et al., 1996). The macroscopic characteristics of the fabric resemble much some products from the Baetican coast (*e.g.* Cádiz area) related to the same amphora type, but the petrographic composition (in particular the accessory basic igneous contribution) does not seem to support a provenance in Cádiz. Further petrographic studies from the production centres are needed in order to determine the precise provenance of this fabric.

Another well represented Hispanic fabric group is ILU-4, with seven samples whose petrographic characteristics support the hypothesis of a Balearic provenance (probably Ebusitan) suggested by the typological information for many of them. More than one production seems to be represented, considering the petrographic and chemical variability between the samples of this group. These are very fine fabrics, usually with a calcareous composition (but with certain variations in the CaO content) and rich in phyllosilicates. Even if no Late Roman amphora workshops have been published for the Balearic Islands so far, the chemical-petrographic composition may be clearly associated with amphorae from Eivissa (see for comparison Buxeda and Cau, 1997, 2004; Buxeda et al., 1998, 2005).

Besides these most represented fabric groups, the analysis shows the presence of another nine fabrics represented by one sample only (ILU-7, ILU-9, ILU-14, ILU-17, ILU-18, ILU-19, ILU-20, ILU-21, ILU-22) for which a southern Hispanic provenance seems clear from both the archaeometric and the archaeological evidence. The petrographic characteristics suggest that the majority of them would come from the Baetican coast, though in some cases (ILU-20, ILU-21) a possible provenance in the Cartagena area should not be excluded.

In addition to these fabrics, it is worth mentioning another three fabrics (ILU-12, ILU-24, ILU-25) for which the petrographic composition indicates a probable local/regional provenance. This interpretation is supported also by the comparison with reference materials from the central and northern Catalan coastal territory from the same or previous periods (*e.g.* Buxeda and Cau, 2004; Martínez, 2014). No Late Roman amphora workshops have been identified in this region so far, but these results evidence that a minor amphora production took place, as was suggested also by some archaeological evidence (Keay, 1984; Remolà, 2000).

4.3. Eastern Mediterranean fabrics

The only well represented fabric in the analysed assemblage for which an eastern Mediterranean provenance can be proposed is ILU-23, with four samples of the amphora type LRA 1 (Table 4). This fabric, characterised by the presence of a sandy temper with calcareous and ophiolitic inclusions, is associated with a clearly distinctive chemical composition (CG2). It is a quite characteristic fabric of the LRA 1 amphora type and has been related to a provenance in the area around the Gulf of Iskenderun (northern Syria and *Cilicia* in southern Turkey) or Cyprus, where several workshops are known (Peacock, 1984; Empereur and Picon, 1989; Piéri, 2005; Williams, 2005; Reynolds, 2010). Compared with the published archaeometric data for some of these workshops (*e.g.* Rautman et al., 1999; Gomez et al., 2002; Williams, 2005; Burragato et al., 2007; Waksman et al., 2014), a provenance in the Iskenderun area seems the most probable hypothesis for the samples analysed in this work. However, we could not find a clear correspondence with any particular workshop. Taking into account the geological similarities throughout the Iskenderun area, a more precise provenance hypothesis would require, first, a systematic work of characterisation and publication of reference groups for each production centre, which is still lacking in many of them.

Two fabrics represented by individual samples are also associated with an eastern Mediterranean provenance (Table 4).

The fabric ILU-2, that includes a LRA 2 amphora individual (ILU030), is quite similar to some samples from Argolis (P. Day, pers. comm.), where the production of this type has been documented in the Kounoupi workshop (Megaw and Jones, 1983). Even if there exist other production areas for this type (see Piéri, 2005), this evidence may suggest the Argolis as a probable provenance hypothesis.

The other fabric is ILU-11, observed in a LRA 7 sample (ILU048). A similar fabric has been reported for this type by Peacock and Williams (1986), and it is quite characteristic of the products from the middle Nile valley, related to the use of silty alluvial clays, rich in silicates and iron oxides. Also the rather particular chemical composition of ILU048 is clearly similar to that found on LRA 7 samples from the middle Nile valley by Empereur and Picon (1998).

5. CONCLUSIONS

A total of 96 Late Roman amphorae found in the urban centre of *Iluro*/Mataró have been archaeometrically analysed in this study. In addition to characterising these materials, the comparison with reference groups and databases from various production areas and centres allowed a precise provenance hypothesis for many samples, while for other samples only a general provenance in a certain area or region can be formulated so far. Almost all the transport amphorae found in Late Antique contexts in Mataró were imported, reflecting the arrival of foodstuffs from several Mediterranean regions. For a few amphorae a local/regional provenance can be proposed, evidencing a minor Late Antique production in the eastern Tarraconensis. The archaeometric approach reveals a much higher variability of fabrics than what initially suggested by the archaeological study of the amphora assemblage.

The vast majority of the amphorae are Tunisian and southern Hispanic (especially Baetican) products. Some fabrics and workshops are clearly more represented than others and, usually, associated with the manufacture of one or two main types. However a same type could have been imported from more than one workshop, as observed for some African (*e.g.* Keay 62, Keay 35, Africana IIA), southern Hispanic (*e.g.* Dressel 23, Keay 23) and eastern Mediterranean (LRA 1) amphorae.

The wide variety of fabrics observed in the analysed contexts provides further evidence of the trade activity of *Iluro* in Late Antiquity. A comparable diversity has been recently found in other eastern Tarraconensis consumption centres (Fantuzzi et al., 2015a, 2015b), what indicates the association of these urban centres ―including *Iluro*― with the same long-distance trade networks. The arrival to these centres of similar transport amphorae (and their contents) from northern Africa, the south of Hispania and the eastern Mediterranean, among other regions, is a clear evidence of these trade interactions.

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