The Port-Vendres 4 Shipwreck Cargo: evidence of the Roman wine trade in the western Mediterranean

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Abstract
The Port-Vendres 4 shipwreck is evidence of coastal export trade between Hispania Citerior and Narbonne in 40/30 BC. The cargo is made up of a particular assemblage of Roman wine amphoras (Pascual 1, Dressel 1B and Lamboglia 2) destined for Gallic markets. Archaeological and archaeometric analyses conducted on a selection of the amphoras allowed the provenance of the cargo to be identified as Hispania Citerior and the central-southern Tyrrhenian coast of Italy. Iluro and/or Baetulo are proposed as the ports of departure, enabling the reconstruction of the trade route and the historical and economic significance of this shipwreck.

Key words
Hispania Citerior, Late Republican period, shipwreck, wine amphoras, trade, provenance study

The frequency of shipwreck finds in the natural harbour of Port-Vendres, Pyrénées Orientales, France, suggests that it was an important shelter for ships trading on the coastal route 33 (Arnaud, 2005: 154, 165–7) linking the north-western Mediterranean provinces, especially when frequent northerly winds lashed the Gulf of Lion (Fig. 1a). Although there is no evidence of a Roman settlement at Port-Vendres, we know that Romans called it 'Portus Veneris', perhaps because of the presence of a temple dedicated to the goddess Venus (Mela, 2.5). The Cap Béar 3, Port-Vendres 4 and Port-Vendres 5 wrecks found in the harbour provide valuable evidence of the significant sea trade conducted between the port cities of Hispania Citerior (named Tarraconensis under Augustus' reorganization) and the Roman city of Narbo Martius (Narbonne), from the mid 1st century BC to the 1st century AD (Liou, 1987; Parker, 1992; Nieto and Raurich, 1998; Kotarba et al., 2007). The cargo of these shipwrecks mainly consisted of amphoras containing wine produced in various areas of north-eastern Hispania.

From the late 2nd century to the early 1st century BC, the political, economic, administrative, social, and cultural evolution of Hispania Citerior drove the progressive development of an economic system based mainly on viticulture and the wine trade. Although Italian wines, packaged in Dressel 1 and Lamboglia 2 amphoras, were still predominant in the western provinces until the early Augustan period, local wine gradually started to compete in the same western markets from the mid 1st century BC onwards (Tchernia, 1987). Recent studies using different approaches—archaeology, landscape archaeology, epigraphy, archaeometry and so on—have led to significant progress in understanding where and when this phenomenon began and how it developed throughout the province (Miró, 1988; Revilla, 2004; Berni et al., 2005; Tremoleda, 2008; Martínez, 2014). Particular emphasis has been placed on analysing wine-production facilities and pottery workshops where amphoras were manufactured. Thus, there are several known wine-production areas in north- eastern Hispania. Both wine and amphora production centres within this region were generally located on the coast or near waterways, ensuring the commercial distribution of the wine surplus. Winemaking and amphora manufacture did not develop simultaneously throughout the province, but gradually. Moreover, varying dynamics in the production processes across the region and through time can be clearly detected. Most of the amphora types (Dressel 1 Citerior, Tarraconense 1, Dressel 7–11 and Oberaden 74) were manufactured only in specific areas, while others (such as Pascual 1 and Dressel 2–4) were produced throughout the territory.

Since viticulture was embedded in the political and economic system imposed by Rome, it started in the earliest Romanized areas of north-eastern Hispania, in the first organized landscapes featuring Roman foundations as central points for catchment and trade, that is the port cities of Tarraco (nowadays Tarragona) in the south, and Iluro (present-day Mataró) in the Laietan region (Fig. 1b). The latter is considered the earliest wine-amphora production area, in which imitations of Italic types (Dressel 1 Citerior) were first adopted in the first half of the 1st century BC and were progressively substituted in the mid 1st century BC by the Tarraconense 1A, 1B, 1C, 1D, 1E repertoire. Since 40/30 BC (López and Martín, 2008; Martínez, 2014: 311–14), the Pascual 1 type progressively replaced the older models in this area, as well as in the first pottery workshops founded in the surroundings of the Roman city of Baetulo (now Badalona) (Buxeda etal.,2002;Martínez,2014:308–11). From30/20BC, previous production areas were reactivated, such as the ager tarraconensis around Tarraco and Iluro (Miró, 1988; Revilla, 2004, 2007, 2010; Tremoleda, 2008; Járrega and Prevosti, 2011). New pottery workshops emerged in the northern area, around the Roman cities of Blandae, Gerunda and Emporiae (now Blanes, Girona and Empu´ ries, respectively) (Tremoleda, 2000, 2008; Martínez, 2014: 314–17), while further pottery workshops appeared in organized territories centred on new Augustan foundations, such as Barcino (present- day Barcelona) (Carreras and Guitart, 2009; Carreras etal.,2013;Martínez,2014:306–8). Thus, the Pascual 1 type was manufactured in all wine-production areas and it was mainly aimed at supplying local and Gallic markets, although it also reached the southern coasts of Britannia and the military camps located in the Germanic limes (Laubenheimer, 2005). Furthermore, at this time the manufacture of minor types began, such as the Oberaden 74 and Dressel 7–11 designs, the production of which was limited to the pottery workshops located in the northern and southern areas. This variety of major and minor amphora designs in the same workshops is probably attributable to a variation in wine categories and trade conditions. While there is no clear evidence of the commercial diffusion of the Dressel 7–11 type produced in north-eastern Hispania, the Oberaden 74 type seems predominantly destined for the military camps of the Germanic limes (González and Tremmel, 2011–2012; Carreras and González, 2012). In the last decades of the 1st century BC, a new amphora adopted from the Italic repertoire— Dressel 2–4—was introduced in the Hispanic pottery workshops where earlier amphora types had been produced. Until the first decades of the 1st century AD, Dressel 2–4 was manufactured at the same time as the Pascual 1 type. Although both amphora types shared the same Gallic markets and were exported to the military camps of the limes, the Dressel 2– 4 type was mainly aimed at supplying the Hispanic, Italic and central Mediterranean markets during the Julio-Claudian dynasty (Tchernia, 1971; Tchernia and Zevi, 1974; Corsi-Sciallano and Liou, 1985; Nieto and Raurich, 1998).

Recent epigraphic research has been conducted also on stamps from amphoras found in production centres, shipwrecks and ad destinum contexts (Carreras and Berni, 2002; Carreras and Guitart, 2009; Berni and Carreras, 2013; Carreras et al., 2013). Different sealing practices have been noticed among the types according to the period and the area of manufacture. Although knowledge of the significance of these stamps has notably progressed in recent years, there is still much scientific debate about their meaning, specifically the question of who, within the vineyard economic system, was represented by these names.

The investigation of maritime trade has been favoured by several shipwrecks carrying wine amphoras from north-eastern Spain having been found in the Gulf of Lion. Because of these remains, until a few years ago it was widely assumed that maritime trade between Hispania Citerior-Tarraconensis and Gallia Narbonensis was generally conducted via direct routes carrying homogeneous cargoes with amphoras of the same type and from a single production area (Nieto and Raurich, 1998: 123). This assertion was used to support or validate the hypothesis that wine amphoras were shipped directly from port facilities located next to pottery workshops, generally found on the coast or in nearby fluvial basins. However, recent research focused on the archaeometric characterization of wine amphoras from pottery workshops of north-eastern Spain (Martínez, 2014), shipwrecks (Buxeda et al., 2004; Martínez et al., 2013a, 2013b), and sites of reception and consumption (Barberan et al., 2009; Martínez, 2011–2012, 2013) point to the existence of a variety of trading patterns, differing according to the chronological framework in which each specific site or production area was operating. Thus, it has been demonstrated that the use of this route by ships trading several types of amphora as their main cargo dated to the pre-Augustan or late Augustan period, such as Cap Béar 3 (Dressel 1, Tarraconense 1, Pascual 1 and Dressel 12 amphoras) and Port- Vendres 5 (Pascual 1 and Dressel 2–4 amphoras from the Tarraconensis) respectively, in addition to Port- Vendres 4 (Kotarba et al., 2007: 638–40; Martínez et al., 2013b). The diversity of cargoes and sealing practices attested demonstrates that the mechanisms involved in the economic and trade activities were complex and diversified, leading to different dynamics over the two centuries. Thus, homogeneous cargoes consisting of Pascual 1 amphoras should be more precisely framed in the Augustan period, as observed at Cap del Vol and Els Ullastres shipwrecks found in the northern Catalan coast (Nieto and Raurich, 1998). Nevertheless, even those shipwrecks with uniform cargoes of Pascual 1 amphoras appear to have been involved in redistribution trade. The archaeometric characterization indicates that most of the amphoras from these two cargoes were produced in pottery workshops located at Baetulo (Martínezetal.,2013a). However, amphoras from the hinterland of Iluro were identified also, which suggests coastal shipping between these two cities of the Laietan region. This hypothesis is consistent with the nautical characteristics of the ships, which appear to be appropriate for coastal shipping (Vivar et al., 2013: 105). The archaeometric characterization of amphoras from these cargoes and from redistribution and consumption centres also point out that specific production areas, integrated into the vineyard economic system of production and exchange, took part in this trade more intensively than others. However, little is known still about the relationships between specific production and consumption areas and preferential—provincial and extra-provincial—catchment areas or markets.

As part of a larger project studying the production and trade of wine and wine amphoras produced in north-eastern Hispania, using a combination of archaeological and archaeometric methodologies, we present here the study of the remains from the Port-Vendres 4 shipwreck. Based on the archaeological data, it is assumed that this shipwreck represents a case of redistribution trading from north-eastern Hispania to Narbonne, dated to the second half of the 1st century BC. The varied cargo is composed of multiple wine- amphora types from Italy (Dressel 1B and Lamboglia 2) and Spain (Pascual 1) (Kotarba et al., 2007: 625). The first attempts to identify the origins of Port-Vendres 4's main cargo were made by epigraphic specialists. Taking into account only the Pascual 1 amphoras, Carreras and Berni (2002) associated some stamped, pointed bases with two specific pottery workshops located in the Llobregat river valley. They affirmed therefore that the Pascual 1 amphoras of Port-Vendres 4 were produced, at least partially, in this area. This assertion led them to conclude that they were loaded in the port at the Roman colony of Barcino, where wine amphoras from various nearby sites would have been stored for trade. However, this assessment may be viewed with caution since some of the stamps borne by the Port-Vendres 4 amphoras have been recovered in a range of pottery workshops from different areas of the province. We should stress that homonymy is a common phenomenon observed in Roman wine amphoras from Hispania Citerior- Tarraconensis (Corsi-Sciallano and Liou, 1985: 159; Carreras and Berni, 2002: 359).

In order to provide an updated interpretation of the historical and economic significance of the Port-Vendres 4 shipwreck, an exhaustive review of the materials recovered in the archaeological excavations has been conducted. In addition, a thorough archaeometric characterization of the wine-amphora types and dolia identified as the cargo has been carried out using chemical, mineralogical and petrographic analyses. The main goal was to establish the possible areas of production and place(s) of shipment of the amphoras analysed and, consequently, to define the trade route of the ship and the type of navigation and trade—coastal, direct or redistributive. To do so, all the data from the Pascual 1 amphoras were checked against the analytical database of the ERAAUB team at the University of Barcelona. Likewise, the rest of the materials were compared with the petrographic database of the DISTAV at the University of Genoa, together with bibliographical data. Finally, since many pottery samples show partially greyish surfaces, we also present the results of a preliminary analysis of the weathering processes to which the ceramic pastes were exposed during deposition in a marine environment. Identifying these compositional alteration processes was essential in reporting our archaeometric results accurately and in comparing compositional data from the Port- Vendres 4 amphoras with those from the pottery workshops.

The shipwreck

Port-Vendres 4 is one of several shipwrecks identified in the Port-Vendres roadstead, on the rocky sea-bed extending south of the access to the port. It was discovered by D. Colls in 1983 during the excavation of the shipwreck Port-Vendres 3, which had sunk and partially covered the site in the mid 2nd century AD (Liou, 1973: 573). Colls' findings suggested the existence of a second ship's cargo consisting of Italic Dressel 1B amphoras and Spanish Pascual 1 amphoras (Fig.2) (Liou and Pomey, 1985; Liou, 1987:274; Miró, 1988: 126; Parker, 1992: 332).

Recent archaeological research led by M. Salvat and G. Castellvi between 2005 and 2008 explored 720 m2 through discontinuous surveys, compared with the 50 m2 initially covered (Fig. 3). It was shown that there had been substantial destruction of the site due to the building of a port channel in the 18th century. In these investigations no trace of the hull was found, but it seems that the ship ran aground on the rocky promontory at shallow depth. The hull probably broke up and the wooden remnants were eventually destroyed by marine wood borers. Fragments of Dressel 1B and Pascual 1 amphoras were predominant on the rocks while the Lamboglia 2 type prevailed in the rock concavities and depressions. Individual examples of all types where also recovered on both sides of the promontory. This concentration may well indicate a hypothetical differential position of the three amphora types in the ship's hold. Because the Lamboglia 2 have a more ovoid form than the other types, it is likely that they were sorted by type when being loaded. Furthermore, a large number of copper nails as well as the remains of lead sheets belonging to the hull were also discovered and cannot be attributed to the Port- Vendres 3 wreck, which had iron nails. Their size and shape are also different from those belonging to the Port-Vendres 6 and 7 shipwrecks, dated to the 15th and 16th centuries respectively. Therefore, these copper and lead remains, together with the wine amphoras recovered from the area on both sides of the rocky promontory and in its cracks may originate from the Port-Vendres 4 shipwreck. The fact that the ship sunk on the south side of the pass does not indicate the course followed by the ship before sinking. The position of the remains suggests that the wreck occurred during a north-west wind storm (tramontane). Bearing in mind that the harbour of Port-Vendres was open to the north and east, a damaged ship would be pushed to the side of the harbour opposite to the wind's direction before it could take shelter inside the port.

The cargo

At first, the heterogeneity of the materials recovered led archaeologists to hypothesize the existence of two different cargoes originating from two separate shipwrecks on successive dates: a first containing Dressel 1B and Lamboglia 2 amphoras from Italy, and a second carrying Pascual 1 amphoras from north- eastern Spain. However, the appearance of the three types at the same stratigraphic levels and extending across the same area, as well as the discovery of a few metallic objects probably belonging to the same ship, stimulated the hypothesis of a single shipwreck carrying three different types of wine amphoras. In total, the Minimum Number of Individuals obtained in each case is: 31 Pascual 1, 36 Dressel 1B, 22 Lamboglia 2, one Dressel 1A, one Dressel 1C and a few fragments of dolia (Kotarba et al., 2007: 625). The last two amphora types should probably be ascribed to the crew's use, although they may also have formed part of the commercial cargo, or may be considered as intrusive finds. We should also note that epigraphic stamps were found on all of the three main amphora types.

Pascual 1 amphoras

The Pascual 1 type was introduced in the pottery workshops of the Laietan region from c.40 BC. It was the most widely produced amphora during the period of major expansion of vineyards, wine production and trade, lasting for the whole of Augustus' reign. Several fabrics were identified by macroscopic analysis, mainly corresponding to reddish or light brown pastes. Some of the pointed bases are stamped and, in a few cases, the same signature was found both during the archaeological excavations carried out in the 1980s and in the studies conducted more recently (Liou, 1987: 281, fig. 5; Kotarba et al., 2007: 625).

A square retrograde S stamp appears on at least seven individuals, generally in association with other marks: a 'VS' graffiti and DE, B and TH stamps respectively (Fig. 4). So far the S retrograde stamp has not been found in any known pottery workshop from north-eastern Spain. A similar but smaller stamp was found at Port-la-Nautique (Narbonne) (ANTEAS, 1993: 10, n. 28) on the pointed base of a possible Pascual 1 amphora. Other parallels in a round stamp were discovered in the Roman city of Baetulo (Fig. 1b) (Comas, 1997: n. 169–72, 197), at Port-la-Nautique (ANTEAS 1993: 12, n. 41) and in several shipwrecks: Cap del Vol (Port de la Selva, north-east Spain) dated to 15 BC–AD 10, La Chrétienne H (Saint Raphael, France) dated to the first quarter of the 1st century AD, and Sud Lavezzi 3 (Lavezzi Islands, southern Corsica) dated to the first third of the 1st century AD (Nieto and Foerster, 1980: 176, fig. 12; Santamaria, 1984: fig. 13; Corsi-Sciallano and Liou, 1985: n. 19, fig. 112; Nieto and Raurich, 1998).

The signature TH, together with SOS, QVA, QVALE and E or F, has been identified on reddish and light brown amphora from the Vila Vella-Barri Antic workshop (Fig. 1b), in the lower basin of the Llobregat River, near the Roman city of Barcino (Barcelona) (Carreras and Berni, 2002: 365; Berni and Carreras, 2013: 252–61). Some findings in Fos-sur-Mer and in La Chrétienne H suggest a widespread diffusion in Gaul on Dressel 2–4 amphoras (Amar and Liou, 1984: n. 88, pl. 6; Santamaria, 1984: n. 58, fig. 17).

This version of the AM stamp (Fig. 4) is only known from the Port-Vendres 4 shipwreck. Although it has been associated with the Pascual 1 type, it appears in other morphological variants on Dressel 2–4 amphoras from Sud Lavezzi 3, La Chrétienne H, together with PRI, and in the Grand Rouveau (Embiez Island, Var) shipwrecks (Corsi-Sciallano and Liou, 1985: 54, 79, 137).

The CHR stamp is widely known on amphoras from the El Morépottery workshop (Sant Pol de Mar, Maresme) (Martínez, 2014: 313) and in the nearby workshopatCanRodón(CabreradeMar)(Lópezand Martín, 2008) (Fig. 1b). This stamp has been reported in two variants in both production centres: one square, similar or identical to that of Port-Vendres 4, and a second in which the signature is inscribed in a round stamp. However, Carreras and Berni (2002: 365) have linked this stamp to the amphoras produced at the villa of Can Feu

(Sant Quirze del Vallès). An illegible square stamp together with a circular stamp and a vertical graffiti has also been identified on a Pascual 1 pointed base (Fig. 4).

Dressel 1B amphoras

The Dressel 1B is considered to be the most common amphora type for the wine trade from the Tyrrhenian coast of Italy to the western provinces from the last third of the 2nd century BC to the last third of the 1st century BC, when it was progressively replaced by the Dressel 2–4 type (Tchernia, 1986: 42–8; Hesnard et al., 1989). A wide morphological diversity among the lips of the Dressel 1B type from Port-Vendres 4 was observed, coinciding with the presence of different macroscopic fabrics (Fig. 5). One individual was stamped Timotheus while another fragment bore the stamp P. Veveius Papus along with Nicolaus (Fig. 6). This combination can be found also among the stamps recovered at the La Madrague de Giens shipwreck (Var), dated to 75–60 BC (Tchernia et al., 1978: 15–17).

Lamboglia 2 amphoras

The Lamboglia 2 wine amphora was mostly produced along the Adriatic coast from the last third of the 2nd century BC to the last third of the 1st century BC, when it was progressively replaced by the type Dressel 6A (Tchernia, 1986: 53–5; Cambi, 1989; Lindhagen, 2009, 2013; Carre et al., 2014). The Lamboglia 2 was diffused together with the Dressel 1 type both in the eastern and western Mediterranean provinces. According to some scholars (Tchernia, 1986: 54; Cipriano and Carre, 1989; Hesnard, 1998: 307) the macroscopic characteristics of some Lamboglia 2 amphoras suggest a minor production in the Campanian region.

A review of the pottery materials recovered in the 1980s demonstrated that some of the shapeless fragments previously attributed to the Dressel 1B type are in fact fragments of the Lamboglia 2 type. The latter was by far the most common type in the rock concavities and on both sides of the promontory's faults (Fig. 7). Some complete or nearly complete amphoras present similar profiles recalling the Lamboglia 2 recovered in Sud-Caveaux 1 shipwreck (Marseille), with which Port-Vendres 4 shares some characteristics. Lamboglia 2 amphoras from Sud-Caveaux 1 consist of a great diversity of shapes and they appear together with an assemblage of the earliest Dressel 6A. All these amphoras were reused to transport resin as the main cargo at c.30 BC (Long, 1998: 347), and they were loaded together with a few variants of the Tarraconense 1 amphora type from Hispania Citerior. Even if the Lamboglia 2 and the Dressel 6A amphora types present some common typological features (cylinder-shaped neck, distinct carination between the shoulder and the body and ovoid handle section) that sometimes makes correct typological assignment difficult, the profile characteristics of the amphoras from Port- Vendres 4 favour their attribution to the Lamboglia 2 type. Moreover, archaeological data support this assessment since this type was generally traded together with Dressel 1 amphoras, while the type Dressel 6A was mainly diffused with the wine amphoras of type Dressel 2–4 from the Augustan period (Tchernia, 1986; Lindhagen, 2009, 2013; Carre et al., 2014).

Three amphoras from Port-Vendres 4 bear the stamp M.LOLLIQ.F on the lip or neck (Figs 6, 7). The same stamp has been recovered on the same amphora type from La Madrague de Giens and from Tharros (Sardinia), being attributed to a Campanian origin (Liou and Pomey, 1985: 563). According to A. Hesnard (1998: 308–9) it refers to M. Lollius Q.f., who is mentioned by Cicero as an adolescent in his account of the trial of Verres (Verr. III: 61–3) in 70 BC. From this source it is assumed that M. Lollius Q. inherited lands in Campania from his father Q. Lollius at some time after this date, and that he may have managed them during the following decades. This coincides with the proposed date of the sinking of the La Madrague de Giens shipwreck (75–60 BC). Since the Pascual 1 type began to be manufactured from 40/30 BC, the Port-Vendres 4 shipwreck must be dated to this period, when M. Lollius Q. would have been around 50 years old; besides, a date of 40/30 BC is entirely consistent with what we know of the earliest imports of Pascual 1 amphoras in Gaul (Col de la Vayède en Provence), dated to the mid 1st century BC. According to Lindhagen

(2009: 101, 2013: 238–9), M. Lollius Q. imitated the Adriatic Lamboglia 2 amphora in the Campanian region ‘in order to compete more successfully on the eastern wine market, where this container was dominant’. However, the finds at Port-Vendres 4, La Madrague de Giens and in Sardinia prove that they were also traded to the western Mediterranean.

Dolia

Three fragments of dolia were recovered in the 1983 surveys (Liou and Pomey, 1985: 553; Liou, 1987: 274). One of these fragments has a peculiar closing device, a round ceramic stopper surrounded by a lead structure sealing a previous hole (Fig. 6). A Greek inscription, ΔI¥Ω meaning ‘I’m thirsty’, was found on the rim of the lead structure. Macroscopic examination revealed that the paste of the top differs from that of the dolium itself, which was attributed to an origin in Tarraconensis. A third fragment of dolium was ascribed to an Italic provenance (Kotarba et al., 2007: 625).

Sampling and analytical techniques

The samples analysed came from 39 representative individuals of Pascual 1 (PV4001, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 38), Dressel 1B (PV4017, 21, 22, 23, 24, 25, 33, 35, 36, 37) and Lamboglia 2 (PV4026, 27, 28, 29, 30, 31, 32) amphoras, and three fragments of dolia (Table 1). Two main groups of the Pascual 1 type were distinguished macroscopically on the basis of their paste characteristics: ten individuals presented a reddish paste colour (PV4001, 2, 3, 4, 8, 10, 11, 15, 16, 38) and seven a light brown colour (PV4005, 6, 7, 9, 12, 13, 14). However, most samples presented surfaces with a greyish hue due to alterations caused by seawater, as documented elsewhere (Buxeda et al., 2004, 2005; Martínez et al., 2013a).

The archaeometric study involved chemical, mineralogical and petrographic characterization (Tite, 2008). Thin-section analysis under a polarizing microscope (Olympus BX51) was performed on all sherds. In allowing comparison between the mineralogical and petrographic characteristics of the inclusions of the pastes and the geology of the production areas, this technique is very useful in studying the provenance of pottery sherds. Moreover,

the analysis of the paste texture can contribute to the reconstruction of the technological processes of the pottery manufacture, including raw materials procurement and processing, forming and firing. Petrographic fabrics were defined on the basis of the composition and characteristics of the microstructure (micromass) and matrix (groundmass), as well as the type, shape, size, frequency and distribution of non-plastic inclusions, as proposed by Whitbread (1995). Specific attention was paid here to stamped amphoras. One Lamboglia 2 (PV4027) and four Pascual 1 (PV4008, 15, 16, 38) types analysed bore epigraphic stamps: M.LOLLIQ.F, AM, S, TH with S and CHR respectively (Figs 4, 6).

Chemical composition was determined by X- Ray Fluorescence (XRF) and, when combined with a multivariate statistical analysis, specific pottery production sites could be distinguished. Mineralogical analysis was carried out with X-Ray Diffraction (XRD), enabling us to estimate the firing conditions (atmosphere and temperature). This technique is also very valuable in identifying weathering processes resulting from the burial of pottery sherds. Geochemical analysis by XRF and mineralogical analysis by XRD were carried out on powdered specimens, except for sherds 3, 10, 15, 19, 20, 24 and 39, at the CCiT-UB technology centre at the University of Barcelona. XRF was performed using a Philips PW 2400 spectrometer while XRD measurements were carried out using a Siemens D500 diffractometer. Measurements were taken following the same procedures as previous studies (Martínez et al., 2013a).

Two selected samples (PV4012 and PV4023) were submitted for SEM-EDS analysis to gain a better understanding of weathering processes occurring in a marine environment of deposition. The analysis was performed at the DISTAV laboratory at the University of Genova using a Philips SEM 515 scanning electron microscope equipped with an energy- dispersive spectrometer (EDS PV9100).

Petrographic analysis

Pascual 1 amphoras

Most of the samples analysed are characterized by the presence of subangular to subrounded fragments of granitoid rocks and derived mineral individuals (quartz, plagioclase, K-feldspar, muscovite and biotite) as main aplastic inclusions in the coarse fraction. Inclusions are generally moderately abundant to abundant and poorly sorted. However, differences in their clay matrix composition, textural features, relative percentages of inclusions and accessory components allowed eight fabrics or petrographic groups to be distinguished (Table 2).

In three petrographic fabrics, P1-A (PV4001, 2, 3, 4, 10, 11, 15, 16) including two amphoras bearing S (PV4015) and TH combined with S (PV4016) stamps (Fig. 8a), P1-B (PV4038) an amphora bearing the tria nomina CHR stamp (Fig. 8b), and P1-C (PV4008) an amphora with the stamp AM (Fig. 8c), the clay matrix is Fe-rich, reddish-brown in plane polarized light (PPL), depending on the firing temperature, with a coarse fraction of medium-very coarse sand fractions (<1.5 mm). Although the petrographic composition varies slightly among these groups, it is compatible with that of the Fe-rich alluvial sediments deposited on the coastal plain of the Laietan region, where a number of potteryworkshopswerelocated(Martínez,2014:303– 6, 311–14). The aplastic inclusions originated in the Paleozoic granitic basement of the Serralada Litoral and Pre-litoral (coastal and pre-coastal mountain ranges).

Fabric P1-D (PV4006) (Fig. 8d) presents a Fe-rich clay matrix including Ca-rich clay lumps, and appears yellowish-brown in PPL. It differs considerably from the previous groups due to abundant medium-grained sedimentary and metamorphic inclusions (Table 2). On a petrographic basis it is difficult to suggest a precise provenance area for this sherd. However, the fabric resembles those of some amphora productions from the southern area (ager Tarraconensis and the lower Ebro basin) (Fig. 1b) (Martínez, 2014: 301– 3).

Fabrics P1-E (PV4012) (Fig. 8e), P1-F (PV4005 and PV4007) (Fig. 8f) and P1-G (PV4009) (Fig. 8g) are characterized by a calcareous clay matrix, generally vitrified and light brown or greenish-brown in PPL (Table 2). Coarse inclusions are moderate to abundant and grain size corresponds to a coarse sand fraction, slightly finer in fabric P1-F (<1 mm) than in P1-E and P1-G (<1.5 mm). The latter two fabrics are similar to those of the Pascual 1 amphora produced at the pottery workshops located in the lower basin of the Beso`s river, near the Roman city of Baetulo, coeval to thecityofIlurolocated20kmtothenorth(Martínez, 2014: 308–11) (Fig. 1b). Finally, fabric P1-H (PV4013 and PV4014) (Fig. 8h) has a calcareous matrix, poorly vitrified and light greenish-brown in PPL. This fabric mainly differs from the previous ones in that coarse inclusions are moderately abundant, fine-medium grain sized (<0.5 mm) (Table 2).

The petrographic composition and certain textural features could suggest the use of alluvial or marine sand temper added to the carbonate-rich clays in fabrics P1-D, P1-E, P1-F, P1-G, and P1-H. The clayey raw materials of these productions can be sourced from the Tertiary and Quaternary sediments outcropping in the central and southern coast of present-day Catalonia, where sedimentary complexes are intercalated with the Palaeozoic granitic basement (Martínez, 2014).

Dressel 1B amphoras

Four different petrographic groups were distinguished. Most of the samples analysed present a clay matrix rich in Fe-oxides with subordinate carbonate contents, dark reddish-brown (D1-A and D1-C) and light brown (D1-B) in PPL. These fabrics are characterized by the presence of fine-medium grained inclusions (<0.4 mm), consisting of variable percentages of elements derived from alkali-potassic volcanic rocks and other accessory components (Table 2).

In fabric D1-A (PV4022 and PV4036) (Fig. 9a), inclusions are essentially made up of volcanic elements (clinopyroxene, opaque mineral individuals, basalt and trachyte fragments, rarer sanidine, plagioclase and amphibole), quartz grains and Ca-microfossils (foraminifera and shell fragments). Volcanic inclusions are also frequent in fabric D1-B (PV4017) (Fig. 9b) but their percentage is lower than in fabric D1-A. This fabric also differs in its lower ratio of carbonates and the common presence of chert fragments. Fabric D1-C (PV4021, 23, 24, 25, 35, 37) (Figs 9c, 9d) is characterized by a frequent calcareous component (limestone, Ca-microfossils and shell fragments), partly decomposed in the firing process and altered to secondary micritic calcite; volcanic inclusions are relatively scarce and they appear together with feldspars, chert/radiolarite and metamorphic rock fragments. These fabrics can be attributed to various production centres on the Tyrrhenian coast of Italy according to typological-archaeological data and as a result of the presence of inclusions from the alkali-potassic volcanic complexes of Plio-Pleistocenic age outcropping in southern Tuscany, Latium and Campania.

The PV4033 (D1-D) sample corresponds to a large fragment of the body of an amphora that was initially attributed to the Lamboglia 2 type. However, recent examination indicates that this container is closer to the Dressel 1 type, since the body is cylinder- shaped and the carination displayed on the junction between the neck and the shoulder is noticeable. The amphora presents a Fe-rich vitrified clay matrix, brownish-orange under PPL (Fig. 9e). Inclusions are fine-medium grained (<0.5 mm, occasionally up to 1.5 mm) and angular, abundant and moderately sorted. An acid metamorphic component is dominant, mostly composed of gneiss and quartz-micaschist fragments and quartz, feldspar, and (fine) mica individuals. Radiolarian chert and sandstone fragments are rare, while no volcanic elements were detected. The lack of volcanites seems to exclude an origin from workshops in Latium and Campania, whereas the significant presence of acid metamorphites, in association with terrigenous rocks, would point to southern Tuscany as the possible production area.

Lamboglia 2 amphoras

Two very different fabrics were identified, characterized by inclusions derived from alkali-potassic volcanites (Table 2). Fabric L2-A (PV4031 and PV4032) (Fig. 9f) is similar to fabric D1-C. The clay matrix is Fe-rich with subordinate carbonates, and brownish-orange under PPL. Coarse fraction is abundant, angular to subrounded, fine-medium grained (<0.5 mm), and made up of a metamorphic (quartz, K-feldspar, subordinate acid metamorphic rock fragments), volcanic (sanidine, plagioclase, clinopyroxene, volcanic rock fragments), and sedimentary components (calcareous microfossils, limestone, and subordinate radiolarian chert fragments). Fabric L2-B (PV4026, 27, 28, 29, 30) (Figs 9g, 9h) presents a Fe-rich clay matrix, reddish-brown in PPL or greenish in some areas. Coarse aplastic inclusions are moderately abundant to abundant, fine-medium grained (<0.5 mm), subangular to subrounded. They consist mainly of basalt and trachyte fragments together with clinopyroxene and olivine; quartz, plagioclase, sanidine and opaque minerals are frequent; a few micrite nodules appear as the only calcareous component. Two distinct origins can be suggested for these groups, both located on the Tyrrhenian coast of Italy.

Dolia

Two fragments of dolia (PV4019 and PV4039), one repaired using the lead device previously described (Fig. 6), exhibit the same paste composition (fabric DOL1). The coarse inclusions consist mainly of acid volcanic rock, basalt, chert/radiolarite fragments, muscovite, quartz and plagioclase crystals (Table 2, Figs 10a, 10b). The petrographic composition suggests a possible provenance from the Aegean area, which is consistent with the Greek inscription found on the lead surface, although an origin on the Tyrrhenian coast of Italy cannot be excluded. However, the petrographic data (notably the volcanic inclusions) allow the previous hypothesis of an origin in north- eastern Hispania to be discarded (Kotarba et al., 2007: 625). The ceramic top in the lead device was not analysed in thin section, but macroscopically it resembles the pastes of the Dressel 1B amphoras. Therefore, it is possible that this dolium was repaired somewhere on the Tyrrhenian coast. The third sample (PV4020) shows a different petrographic composition (fabric DOL2), rather similar to group D1C of the Dressel 1B amphoras (Figs 10c, 10d). In this case, an Italic provenance is reasonably certain.

Analysis of weathering processes

Some amphoras, especially of the Dressel 1B type, show greyish/brownish surfaces as a result of weathering processes occurring during deposition in a marine environment. These secondary processes cause changes in both the chemical and mineralogical compositions (as well in the macroscopic colour) of the pastes and therefore these processes must be identified and examined to achieve a correct interpretation of compositional data.

Thin-section, XRD and SEM-EDS analyses allowed the identification of secondary carbonates (aragonite and magnesium calcite) and sulphides (pyrite) whose crystallization is related to deposition in a seawater environment, as demonstrated in previous studies (Picon, 1986; Béarat et al., 1992; Pradell et al., 1996; Amadori et al., 2002; Cau et al., 2002; Buxeda et al., 2004, 2005; Secco et al., 2011; Martínez et al., 2013a; Montana et al., 2014).

Both Mg-calcite and aragonite are typical seawater carbonates which frequently occur as aggregates in the voids of pottery sherds. Mg-calcite was identified by XRD, which may well have been produced by biogenic processes in relatively shallow seawater. Aragonite was also identified by XRD, SEM-EDS and thin-section analyses (Figs 11a, 11b).

Pyrite, whose presence was detected by XRD and thin-section analyses (Figs 11c, 11d), occurs mostly in the voids and frequently grows in concentrated layers a few millimetres under the sherds' surfaces. In some cases, pyrite forms subrounded, framboidal aggregates that were easily detectable by SEM-EDS (Figs 11e, 11f). Their formation originates in anoxic depositional conditions, where the sulphate ion (SO_4^{2-}) present in seawater is reduced to hydrogen sulphite (H_2S) as a result of anaerobic respiration of sulphate-reducing bacteria. Part of this sulphite tends to react with haematite crystals present in the ceramic material to form metastable sulphide minerals, among which pyrite (FeS_2) is the most common (Buxeda et al., 2004, 2005). The neoformed pyrite is mainly responsible for the greyish or dark brownish colour (depending, respectively, on the Ca and Fe content of the clay matrix of the pastes) acquired by the surfaces or, in some cases, by the whole cross-section of the studied amphoras.

Finally, XRD analyses showed the presence of analcime (Na-zeolite) in two Pascual 1 amphoras (PV4005 and PV4007). Analcime is related to post-depositional alteration and/or contamination processes characteristic of over-fired calcareous ceramics both in terrestrial and underwater environments. Previous studies suggest that this secondary phase might entail perturbations not only in Na_2O, but also in K_2O and Rb values (Schwedt et al., 2006).

Geochemical analysis

The results of the geochemical analyses revealed a high degree of correspondence in the compositional data of the samples with the petrographic fabrics previously defined. The chemical concentrations, determined by XRF, of 32 amphoras (14 Pascual 1, 11 Dressel 1B and 7 Lamboglia 2) from the Port-Vendres 4 shipwreck (Table 3) were statistically analysed according to Buxeda's guidelines (1999). The first step in this statistical evaluation involves calculating the compositional variation matrix (CVM), which provides the total variation and the variability that each element introduces into the data. The value of the resulting total variation was very high (vt = 1.685), indicating a broadly polygenic origin for the sherds analysed. However most importantly the CVM revealed that the main variability was introduced by the following elements or oxides: CaO ($\tau_{.CaO}$ = 10.907), MgO ($\tau_{.MgO}$ = 7.388), Sr ($\tau_{.Sr}$ = 5.530), Ni ($\tau_{.Ni}$ = 4.226), P_2O_5 ($\tau_{.P2O5}$ = 3.864), Ba ($\tau_{.Ba}$ = 3.499), Y ($\tau_{.Y}$ = 3.365), Na_2O ($\tau_{.Na2O}$ = 3.201), Cu ($\tau_{.Cu}$ = 3.070), together with Rb, Ce, Pb, Cr and K_2O.

The variability introduced by some of these elements clearly reflects differences in raw material composition, as observed in the petrographic analysis. Examining the normalized chemical data of the sherds analysed, we observed that the high $\tau_{.Cu}$ value was reported by the Lamboglia 2 amphoras belonging to the L2-B petrographic fabric group, which presented the highest Cu concentration. Moreover, Pb values were higher in most of the Dressel 1B and Lamboglia 2 amphoras than they were in the Pascual 1, and this entails a high $\tau_{.Pb}$ value. The same applies to the $\tau_{.P2O5}$ rate, which can be attributed mainly to the high relative concentrations present in the chemical composition of the amphoras belonging to the D1-A (PV4022 and PV4036) and L2-B (PV4026 to PV4030) petrographic groups compared to the concentrations recorded in the rest of the sherds (Table 3). It should be mentioned that P_2O_5 concentrations are feasibly perturbed in pottery deposited in contact with anthropogenic environments (burials, cultivated areas, and so on) (Maritan and Mazzoli, 2004; Maritan et al., 2009), just as Pb and Cu concentrations are sometimes perturbed by depositional alteration processes. Since in the case under study we were unable to verify whether the variability in P_2O_5, Pb and Cu was due to differences in the raw chemical composition of the pottery sherds or to post-depositional perturbation processes, we have discarded these chemical elements in the statistical treatment of compositional data.

As for the trace elements Ni, Y, Ce and Cr, in which post-depositional alterations are unlikely, the high $\tau_{.i}$ values must be attributable to the varying chemical composition of the amphora sherds because of their diverse origins. Relative values of Ni are generally higher in the Dressel 1B and Lamboglia 2 amphoras, but also in the Pascual 1 amphoras belonging to petrographic groups P1-D, F, H (Table 3). Relative values of Y and Ce are higher in Pascual 1 amphoras from group P1-A, whereas the relative values of Cr and MnO are higher in the Lamboglia 2 amphoras from group L2-B. Nevertheless, some of the chemical variability — especially with regards to CaO, Na_2O, K_2O, Rb and Sr — clearly corresponds to the weathering processes previously described, and therefore these elements were also excluded from statistical analysis.

In order to establish accurately the production area of the Pascual 1 amphoras, the chemical composition was checked against the ERAAUB’s analytical databases (Martínez, 2014) of the amphoras produced at 18 workshops sited along the Catalan coastline (Fig. 1b).

The chemical data evaluated (MgO, SiO_2 , TiO_2 , V, Cr, Fe_2O_3, Ni, Zn, Ga, Y, Zr, Nb, Ba and Ce sub- composition) was transformed into log-ratios using Al_2O_3 as divisor. The chemical results are summarized in the biplot of the first two principal components, resulting from the corresponding analysis applied to the previous sub-composition (Fig. 12). In this graph, which contains 82% of the variability, the sherds analysed are divided into two main groups: Pascual 1 amphoras on the left, and Dressel 1B and Lamboglia 2 amphoras on the right of the biplot. It should be noted that the chemical groups coincide with the previously established petrographic fabrics.

In the case of the Pascual 1 amphoras, the chemical analysis confirms the existence of a wide range of amphora productions (Fig. 12). Comparison with the reference groups enabled us to attribute some amphoras to a specific area of provenance. Thus, the reddish pastes of fabric P1-A—PV4001, 2, 4, 11 and the S (PV4015) and TH combined with S (PV4016) stamps—match the amphoras produced in theVallès area near the lower basin of the Llobregat River (Fig. 1b) (Martínez, 2014: 303–6). These pastes have very high relative contents of TiO_2, Zr, Y, Ce and V (Table 3). By contrast, the reddish pastes PV4038 (P1-B fabric) and PV4008 (fabric P1-C) present marked chemical similarities with amphoras produced in the Maresme region, near the Roman city of Iluro (Mataró). Specifically, PV4038 can be clearly attributed to the El Moré workshop at Sant Pol de Mar (Maresme) (Martínez, 2014: 313). It should be stressed that these chemical results concur with the archaeological record, as other exemplars bearing the same CHR stamp have been recovered at this workshop. This amphora production is characterized by a higher relative content of Al_2O_3 and Ce and a very low CaO concentration. The provenance of sherd PV4008, bearing the AM stamp, can also be ascribed to one of the production sites in the area around Iluro since its chemical and petrographic composition resembles amphoras produced in workshops at Cabrera de Mar or Calella (Fig. 1b) (Martínez et al., 2005; Vila et al., 2009; Martínez, 2014: 311–14). It presents higher relative concentrations of SiO_2 and Zr and lower relative concentrations of TiO_2 and Zn.

The calcareous sherds PV4006 (fabric P1-D), PV4005, PV4007 (fabric P1-F), in addition to PV4012 (fabric P1-E) and PV4009 (fabric P1-G) present the greatest relative MgO and Ba values in the whole data set. However, they also show a number of significant chemical differences: most notably the Al_2O_3, TiO_2 and Fe_2O_3 concentrations are clearly higher in individuals PV4005, 6 and 7

(Table 3). Figure 12 shows that PV4006, PV4009 and PV4012 are more similar in chemical terms to the amphoras produced along the Besos river valley, close to the Roman city of Baetulo (Buxeda et al., 2002; Martínez, 2014: 308–11). The amphoras PV4005 and PV4007 (group P1-F) are closer in chemical terms to the calcareous amphoras with high magnesium content produced in workshops of different areas, such as those located around Baetulo or in the southern area, near the Ebro River (Fig. 1b) (Martínez, 2014).ThecalcareousPascual1amphoras PV4013 and PV4014 (fabric P1-H) present a similar chemical composition to the amphoras of group P1-F (high CaO and Ni relative content), but the MgO concentration is lower. The provenance of these two amphoras is still uncertain but we can rule out the possibility of their production in any of the workshops considered here.

The Italic amphoras form a range of groups (on the right of Fig. 12). Dressel 1B and Lamboglia 2 amphoras belonging to petrographic fabric groups D1-A (PV4022 and PV4036) and L2-B (PV4026, 27, 28, 29, 30) are grouped together. They differ markedly from the other Dressel 1B and Lamboglia 2 amphoras because they contain high relative concentrations of Al_2O_3 , Fe_2O_3 and MgO, and higher values in certain trace elements than the rest of the Italic amphoras (Table 3). Their provenance can be traced to the Campania region based on their geochemical and petrographic composition (Hesnard et al., 1989: 38–44; Thierrin-Michael, 2000: 228, 2009: 320, 2007: 124; Thierrin-Michael and Maza, 2002: 465; Olcese and Thierrin-Michael, 2009: 164; Cibecchini and Capelli, 2013: 429; Olcese et al., 2013: 489, 491, 494, 497). Specifically, comparison with archaeological bibliographical data allows us to identify the provenance of amphoras belonging to petrographic fabric group L2-B (bearing the M.LOLLIQ.F stamp) in the Gulf of Naples (Hesnard, 1998: 307).

A marked chemical similarity is also observed between amphoras of both types from petrographic groups D1-C (PV4021, 23, 24, 25, 35, 37) and L2- A (PV4031, 32) (Fig. 12). The provenance of these amphoras may be ascribed to a marginal volcanic area of the Tyrrhenian coast (in southern Tuscany or the Latium region) due to the relative frequency of quartz and acid metamorphic inclusions and the scarcity of volcanic components (Thierrin-Michael, 2000: 227– 8; Olcese and Thierrin-Michael, 2009: 164; Menchelli et al., 2013: 473).

The Dressel 1B amphora (PV4017) with fabric D1-B appears slightly distanced from the preceding group since it is border calcareous and its chemical composition differs from the rest (Fig. 12). It presents high relative values of Y, Zr and Ce, but the relative concentration of the remaining trace elements is lower than that recorded in the two groups described above (Table 3). Its provenance can be traced to somewhere along the coastal belt of Latium and Campania regions, since it is characterized by the presence of Plio-Pleistocenic alkali-potassic volcanic inclusions compatible with this area's geological environment (Thierrin-Michael, 2000: 227–8, 2003: 320–1). In particular, the presence of large crystals of sanidine points to a possible origin around Mondragone (North Campania) (Thierrin- Michael and Maza, 2002: 462; Thierrin-Michael, 2007: 123).

Major chemical differences exist between the sherds analysed and the Dressel 1B amphora PV4033 (petrographic fabric D1-D) (Fig. 12). It presents the highest SiO_2 content and the lowest Ba, Nb and Y relative values of the whole data set (Table 3). Based on archaeological and petrographic data (presence of acid metamorphites in association with terrigenous elements and absence of volcanites), the origin of this amphora may be located in southern Tuscany. It resembles the Graeco-italic amphoras of fabric 7150 from the Cala Rossa shipwreck (Puerto Vecchio, Corsica, 225–210 BC), attributed to a pottery workshop probably located in Etruria (Cibecchini and Capelli, 2013: 431).

Conclusions

The multidisciplinary archaeological archaeometric approach described above proved essential both in identifying the specific provenance of the amphoras recovered at the Port-Vendres 4 shipwreck and to the subsequent reconstruction of the vessel's trade route. More generally, the findings of this study also have important implications for a clearer understanding of the Roman wine trade between Italy, Hispania Citerior and Gallia Transalpine.

The diversity of the amphora types identified in the Port-Vendres 4 wreck suggests a heterogeneous cargo, probably derived from a redistribution trade in which goods from different territories were sold together in Gallic markets. Besides the typological heterogeneity, the archaeometric study reveals that these amphoras were produced in different pottery workshops from various production areas located in Hispania Citerior and on the Tyrrhenian coast of Italy. The presence in the same shipwreck of amphoras from these areas can be attributed to the existence of an important maritime trade between Italy and the western Mediterranean provinces during the 1st century BC. The heterogeneity of provenances found in the Port-Vendres 4 cargo proves that most of the production areas of the Tyrrhenian coast of Italy, the Campania region in particular, exported their goods to the Citerior. Once there, the Italic amphoras were redistributed among the main port cities of the province, as evidenced by the number of Dressel 1 and Lamboglia 2 amphoras found in coeval urban contexts at Emporiae (Aquiluéet al., 2002: 28, fig. 10), Baetulo (Comas, 1998a: 222), and Tarraco (Gebellí, 2008: 49–51) among other cities.

Contrary to earlier assumptions based on the archaeological record, generally attributing an Adriatic origin to the Lamboglia 2 amphoras found in the Mediterranean, this study also confirms the existence of a centre in the Gulf of Naples in which Lamboglia 2 amphoras were imitated, and some of them stamped M.LOLLIQ.F. Furthermore, the present study proves that amphoras previously attributed to the Lamboglia 2 type and to the Adriatic area (possibly the fabric D1- D), as suggested by macroscopic examination (Kotarba et al., 2007: 625), in fact belong to a different type (probably Dressel 1), and their provenance can be placed in southern Tuscany, excluding the Adriatic area. As for the dolia fragments, the diversity of the sherds analysed suggests that they may well be residual materials unrelated to the shipwreck.

Most of the Pascual 1 amphoras analysed here can be attributed to workshops located along the central littoral of the Citerior province, comprising the ancient Laietan region. Some amphoras can be clearly associated with the production areas placed near the Roman cities of Iluro and Baetulo, and this is in accordance with the period of operation of these pottery production areas (Martínez, 2014). In addition, some Pascual 1 amphoras (P1-B) were most probably produced in the winemaking complex of El Moréin the northern Laietan region, generally dated from the Augustan period although a more accurate chronology is still needed. The discovery of several shipwrecks on this route with cargoes consisting mainly of amphoras from the Laietan region (Martínez et al., 2013a, 2013b) is evidence of the important role played by this area in the local wine trade, even though remains of port facilities found up to now in Baetulo and Iluro are few and of minor importance.

The presence on the same ship of Pascual 1 amphoras produced in three main areas of the Laietan region, some 20-25 km distant from each other and around 50 km in total, points to the question of what exactly the trade route followed by the ship was. The absence of the ship and the poor state of conservation of the remains does not offer conclusive data supporting either coastal or direct trade. The former would imply a redistribution trade landing and adding amphoras to the cargo in the harbours of the production areas or of the nearby cities (probably Baetulo, Iluro and/or El Morè). On the contrary, direct trade would require that Port-Vendres 4 loaded all the cargo in a single main port of the Laietan region, where goods from different areas would have been stocked, to the destination port, probably Narbonne (Tchernia, 2003: 614–15). That would involve the existence of a simultaneous redistribution trade, as existed for the local-regional redistribution of Italian wines, to ensure the storage of containers from different provenances in a single warehouse.

Even though some questions remain unanswered, there is no doubt that the Port-Vendres 4 shipwreck sailed from the Laietan region at c.40/30 BC. The economic significance of this ship should also be contextualized. Among the shipwrecks recovered on route 33 (Arnaud, 2005: 154, 165–7), Port-Vendres 4 appears to provide some of the earliest evidence of the maritime trade to Narbonne of Pascual 1 amphoras from Baetulo. This new stage began around 40/30 BC and was characterized by the entrance of the Pascual 1 amphora from this city on to the markets. They were traded together with amphoras manufactured in the pre-existing production areas located around Iluro and in the territories near the Beso` s and the Llobregat rivers, including the littoral and prelittoral (El Vallès) areas. This trade trend was consolidated in the Augustan period, when exports from Baetulo were predominant, as evidenced by the Cap del Vol and Els Ullastres shipwrecks (Martínez et al., 2013a), in addition to a number of urban findings at Narbonne (Martínez, 2011–2012) and other secondary settlements in France (Comas, 1991, 1998b; Laubenheimer, 2005; Barberan et al., 2009; Martínez, 2013), in which amphoras from Baetulo appear to be prevalent. The study of the cargo provides an important insight into how the maritime trade plied between Hispania Citerior and Narbonne was organized, and contributes to a closer understanding of the maritime trade dynamics in the western Mediterranean in the pre-Augustan period.

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Figure captions

Figure 1.
a) Map of the western Mediterranean, marking the location of Port-Vendres; *b)* Map of north-eastern Hispania Citerior, with the location of the main Roman cities and the pottery workshops considered in this study. (V. Martínez)

Figure 2.
Plan of the first surveys conducted at Port-Vendres 4, with indication of the area with dispersed remains. (After D. Colls, 1989: 8, fig. 1)

Figure 3.
Plan of the surveys conducted at Port-Vendres 4 2005–2008. (M. Salvat and G. Castellvi)

Figure 4.
Pointed bases, graffiti and stamps of Pascual 1 amphora from Port-Vendres 4. (M. Salvat)

Figure 5.
Dressel 1B amphoras from Port-Vendres 4. (M. Salvat)

Figure 6.
Stamps and graffiti on Dressel 1B and Lamboglia 2 amphoras; dolium with Greek inscription (PV4019, 39). (M. Salvat)

Figure 7.
Lamboglia 2 amphoras from Port-Vendres 4 shipwreck. (M. Salvat)

Figure 8.
Microphotographs (crossed polars); a: fabric P1- A; b: fabric P1-B; c: fabric P1-C; d: fabric P1-D; e: fabric P1-E; f: fabric P1-F; g: fabric P1-G; h: fabric P1-H. (V. Martínez and C. Capelli)

Figure 9.
Microphotographs (crossed polars); a: fabric D1- A; b: fabric D1-B; c, d: fabric D1-C; e: fabric D1-D; f: fabric L2-A; g, h: fabric L2-B. (V. Martínez and C. Capelli)

Figure 10.
Microphotographs (plane and crossed polars); a, b: fabric DOL1; c, d: fabric DOL2. (V. Martínez and C. Capelli)

Figure 11.
Microphotographs (crossed polars) showing (a, b) secondary crystallization of aragonite and (c, d) pyrite inside the voids; (e, f) SEM images showing secondary crystallization of pyrite (light coloured grains). (V. Martínez and C. Capelli)

Figure 12.
Biplot of the first two principal components showing the distribution of Port-Vendres 4 amphoras compared to references of workshops located in north-eastern Hispania (grey fields). (V. Martínez)

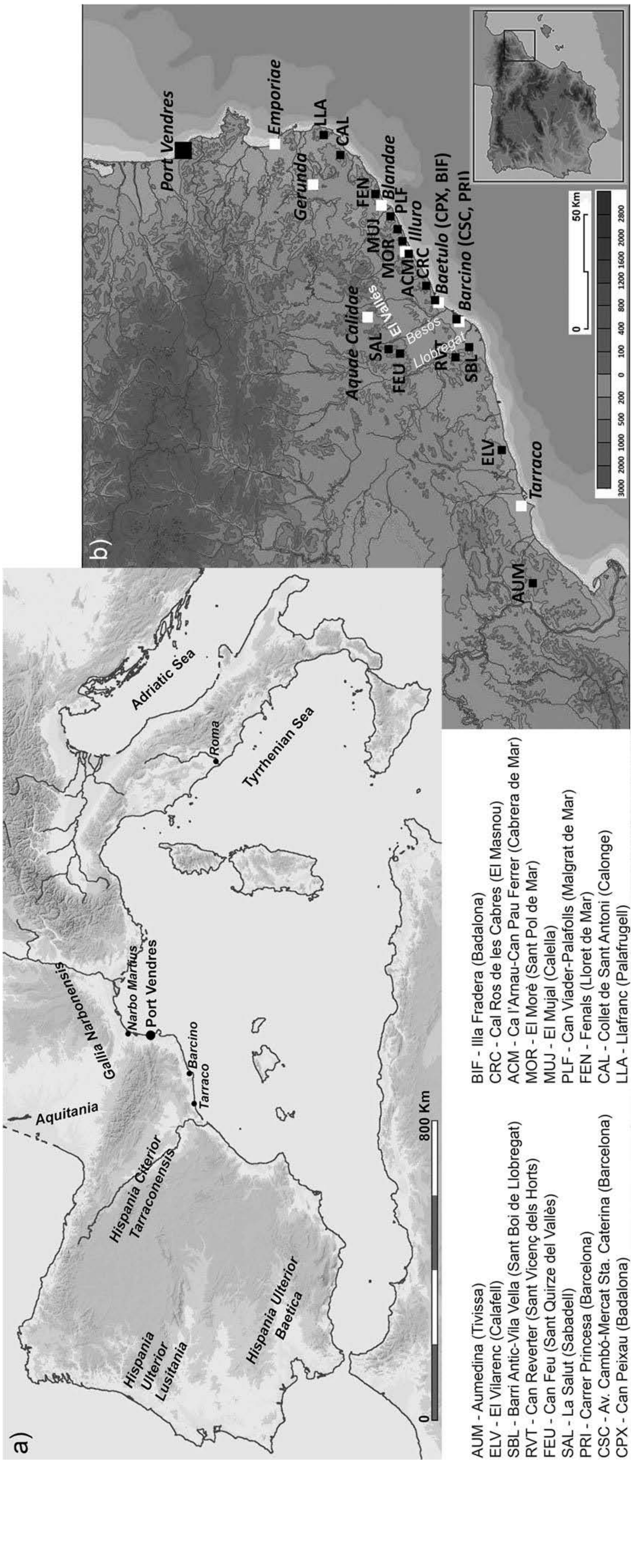
Table captions

Table 1.
Summary and description of amphoras analysed from the Port-Vendres 4 shipwreck

Table 2.
Main textural and compositional characteristics of the petrographic fabrics identified through thin section optical microscopy (OM); V.S. (vitrification state), C.M. (clay matrix), f.f. (fine fraction), c.f. (coarse fraction), Am (amphibole), Bas (basalt), Bt (biotite), Cal (calcite), Ca-microfos (Ca-microfossil),Cht (chert), Cpx (clinopyroxene), Ep (epidote),
Fer (ferruginous), Gns (gneiss), Grnt (granitoid), Kfs (K-feldspar), Ls (limestone), melanitic garnet (Mel-grt), Micsch (micaschist), Ms (muscovite), Ol (olivine), Pl (plagioclase), Qtz (quartz),Qtzt (quartzite), Radiol. (radiolarian), Rhyol (rhyolite), Sa (sanidine), Sst (sandstone), Srp (serpentine), Trach (trachyte), Volc-glass (volcanic glass)

Table 3.
XRF normalised data of the 32 amphoras analysed on the subcomposition Fe_2O_3, Al_2O_3, MnO, P_2O_5, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2 (in %), Ba, Rb, Th, Nb, Pb, Zr, Y, Sr, Ce, Ga, V, Zn, Cu, Ni, Cr (in ppm) and the loss on ignition (LOI) data (in %).

Figure 1



a)
Aquitania
Gallia Narbonensis
Narbo Martius
Port Vendres
Barcino
Tarraco
Hispania Citerior Tarraconensis
Hispania Ulterior Lusitania
Hispania Ulterior Baetica
Adriatic Sea
Roma
Tyrrhenian Sea
0
800 Km
b)
Port Vendres
Emporiae
Gerunda
LLA
CAL
FEN
Blandae
MUJ
MOR
PLF
Iluro
ACM
CRC
Aquae Calidae
El Vallès
Baetulo (CPX, BIF)
Barcino (CSC, PRI)
SAL
FEU
Besòs
Llobregat
RVT
SBL
ELV
Tarraco
AUM
0
50 Km
AUM - Aumedina (Tivissa)
ELV - El Vilarenc (Calafell)
SBL - Barri Antic-Vila Vella (Sant Boi de Llobregat)
RVT - Can Reverter (Sant Vicenç dels Horts)
FEU - Can Feu (Sant Quirze del Vallès)
SAL - La Salut (Sabadell)
PRI - Carrer Princesa (Barcelona)
CSC - Av. Cambó-Mercat Sta. Caterina (Barcelona)
CPX - Can Peixau (Badalona)
BIF - Illa Fradera (Badalona)
CRC - Cal Ros de les Cabres (El Masnou)
ACM - Ca l'Arnau-Can Pau Ferrer (Cabrera de Mar)
MOR - El Moré (Sant Pol de Mar)
MUJ - El Mujal (Calella)
PLF - Can Víader-Palafolls (Malgrat de Mar)
FEN - Fenals (Lloret de Mar)
CAL - Collet de Sant Antoni (Calonge)
LLA - Llafranc (Palafrugell)

Figure 2

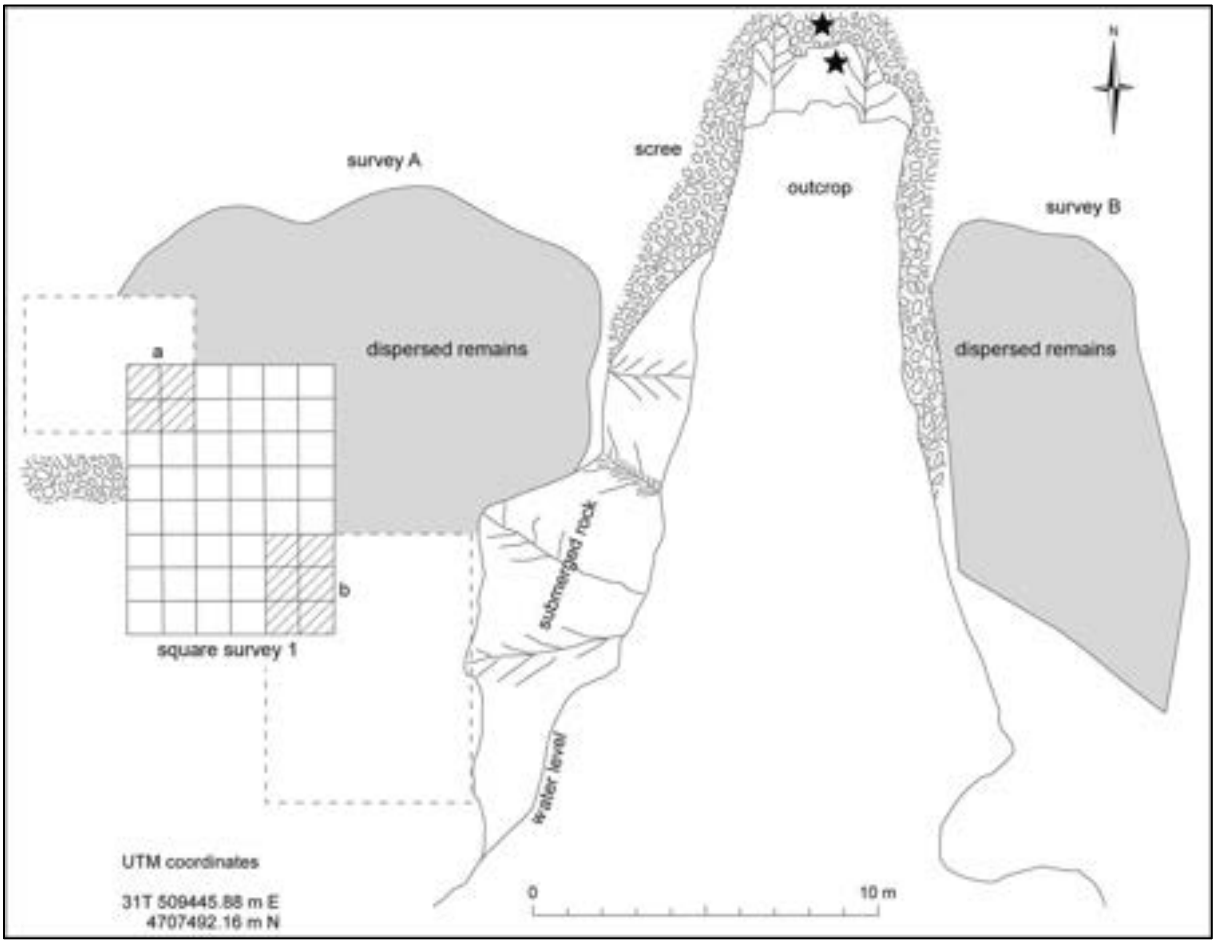

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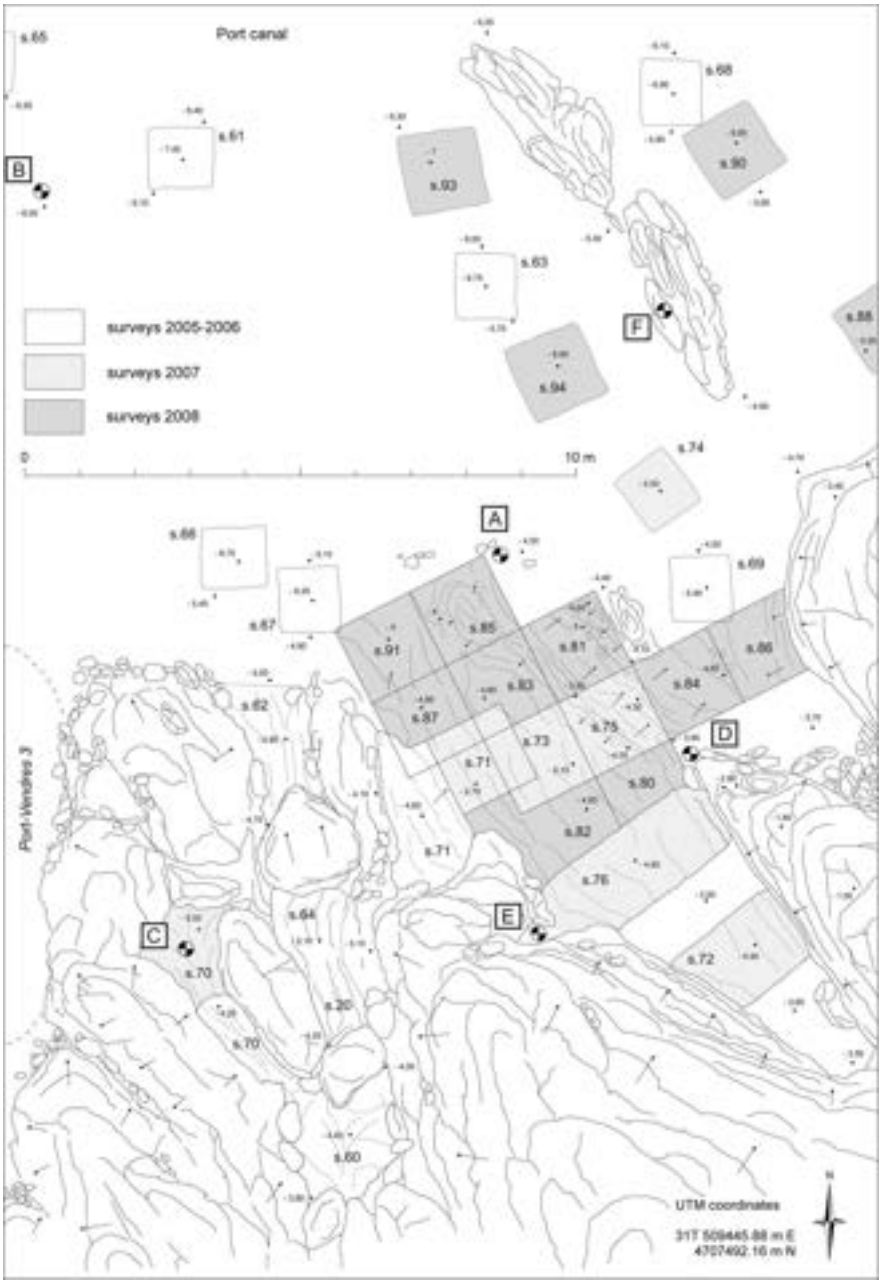
Figure 3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surveys 2005-2006
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Port-Vendres 3
UTM coordinates
31T 509445.88 m E
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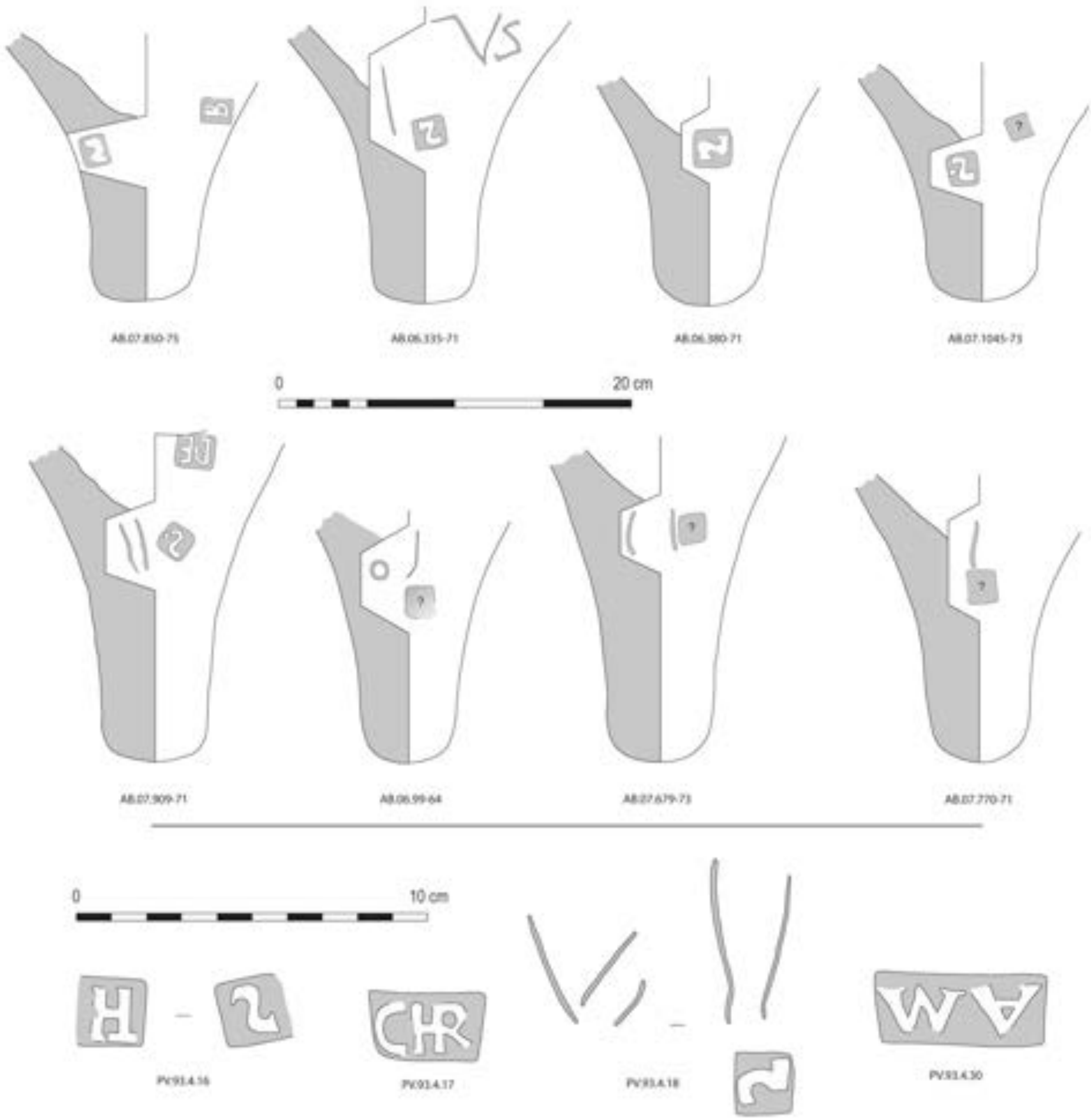
Figure 4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AB.06.335-71
AB.06.380-71
AB.07.1045-73
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AB.07.909-71
AB.06.99-64
AB.07.679-73
AB.07.770-71
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PV.93.4.16
PV.93.4.17
PV.93.4.18
PV.93.4.30

Figure 5

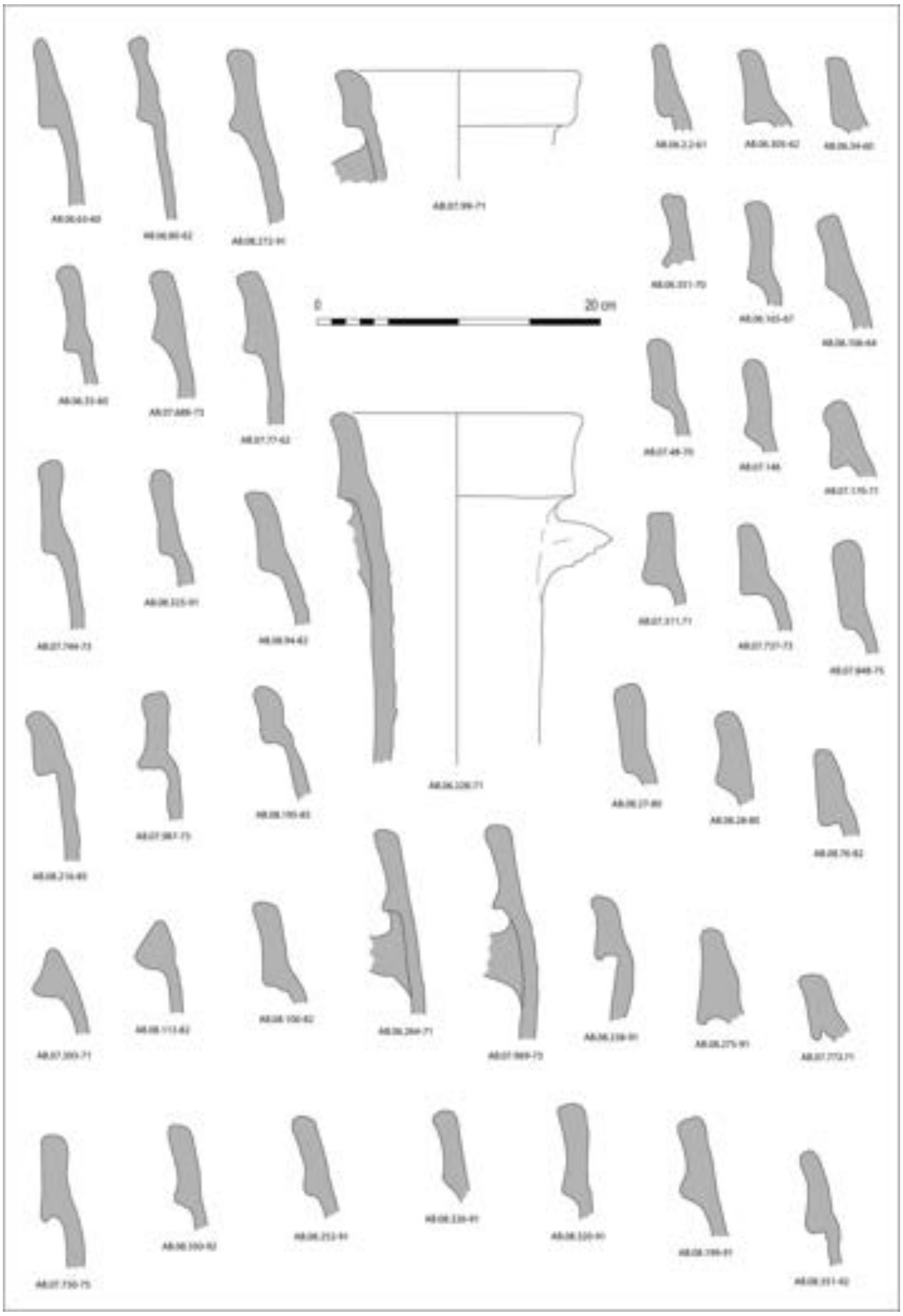


Figure 6

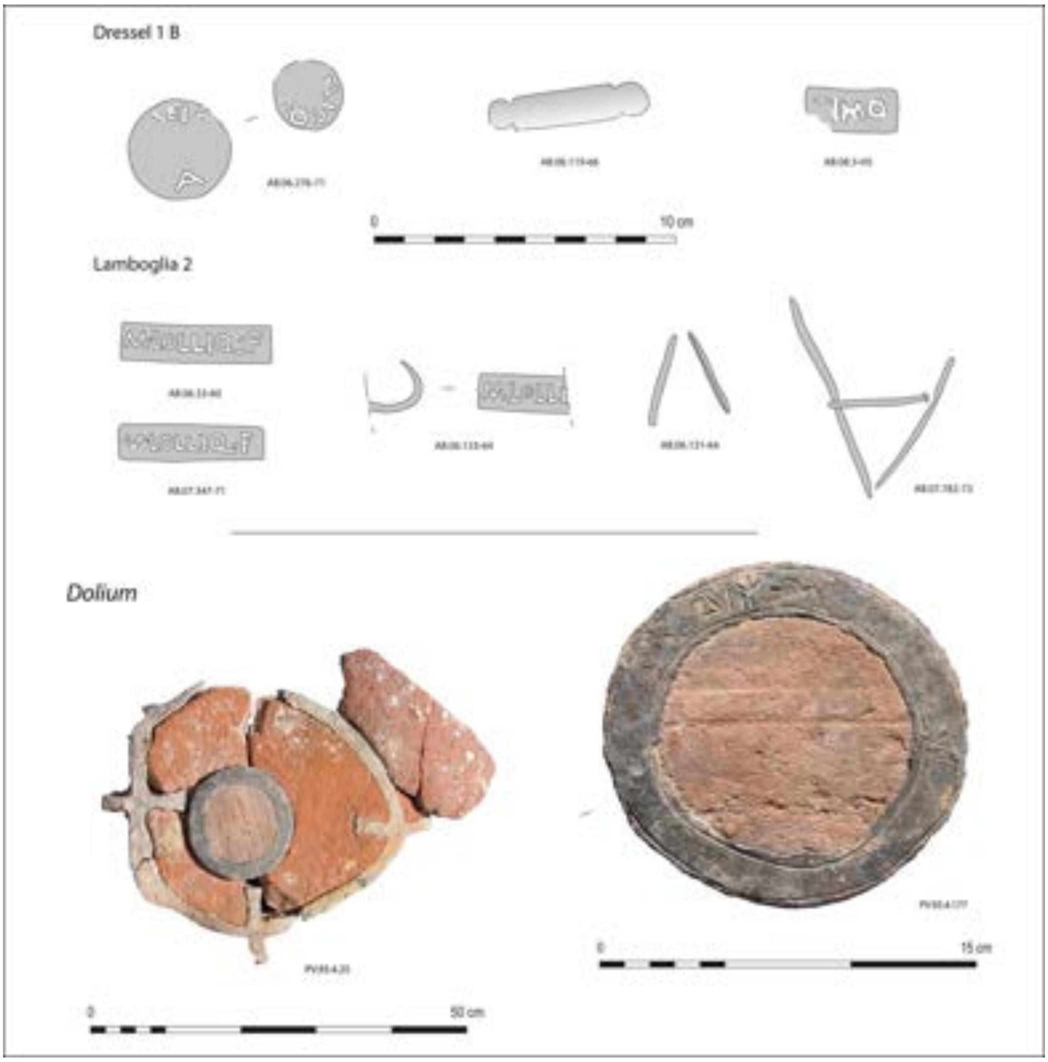


Figure 7

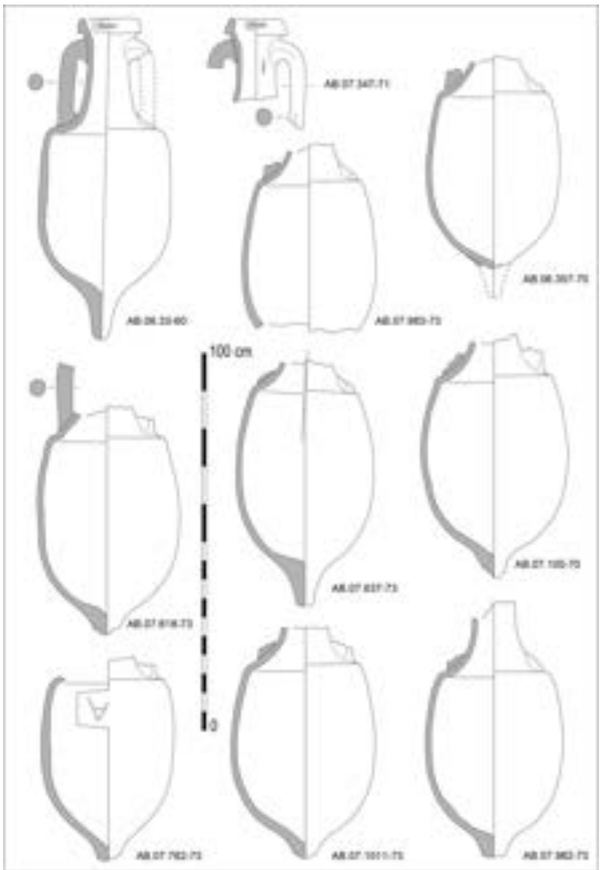
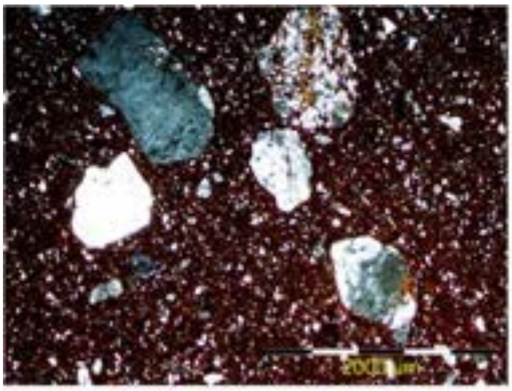
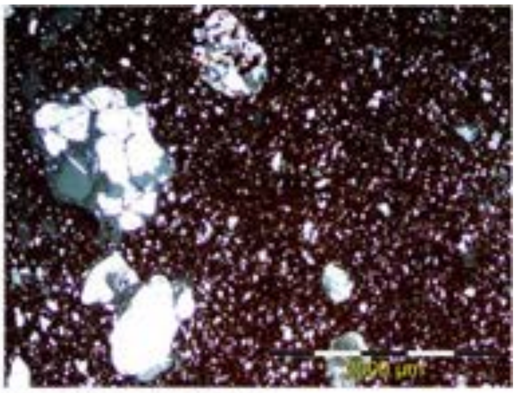


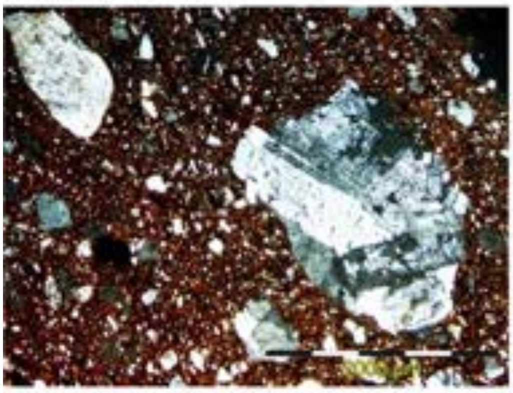
Figure 8



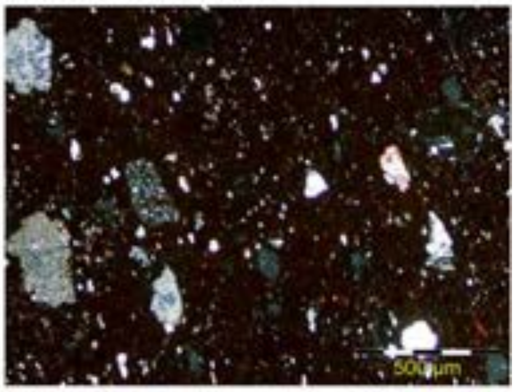
a) PV4002 (P1) 40x XPL



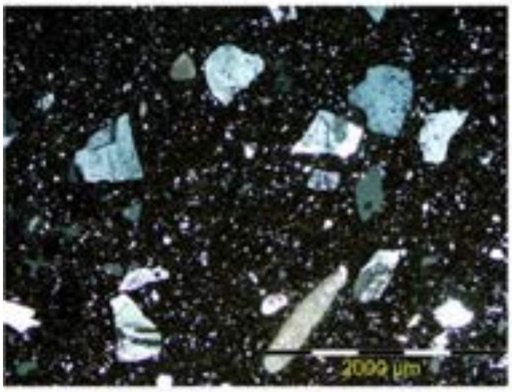
b) PV4038 (P1 s. MA) 40x XPL



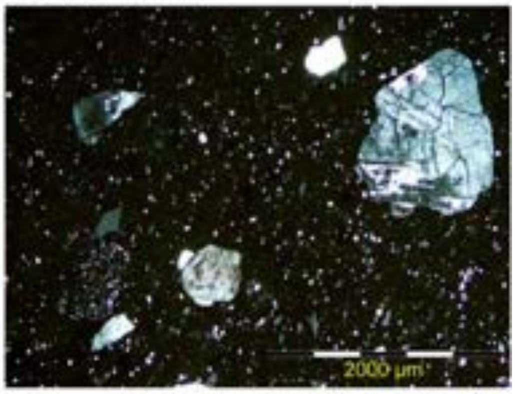
c) PV4008 (P1 s. CHR) 40x XPL



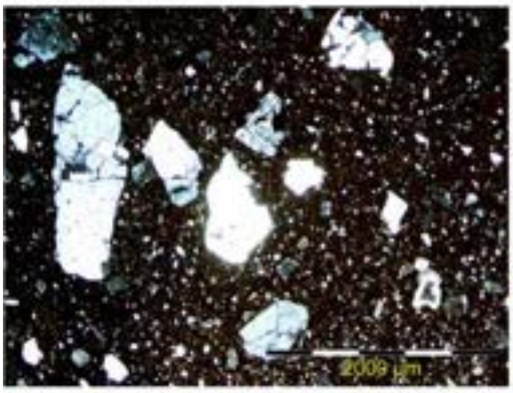
d) PV4006 (P1) 100x XPL



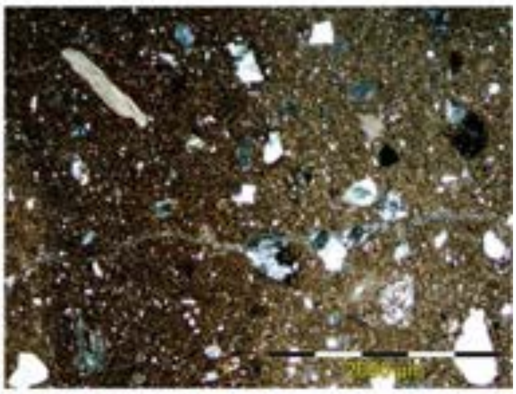
e) PV4012 (P1) 40x XPL



f) PV4007 (P1) 40x XPL

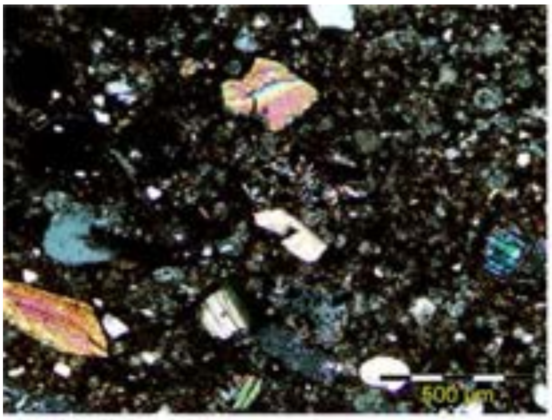


g) PV4009 (P1) 40x XPL

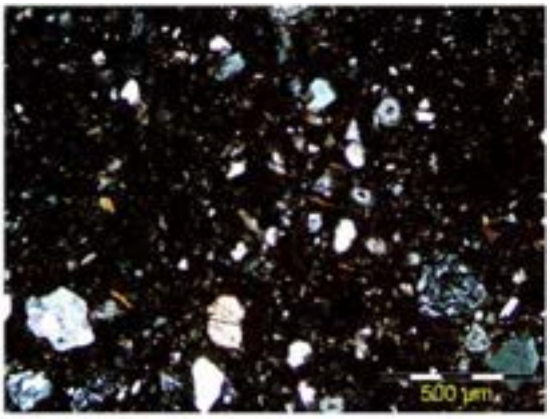


h) PV4014 (P1) 40x XPL

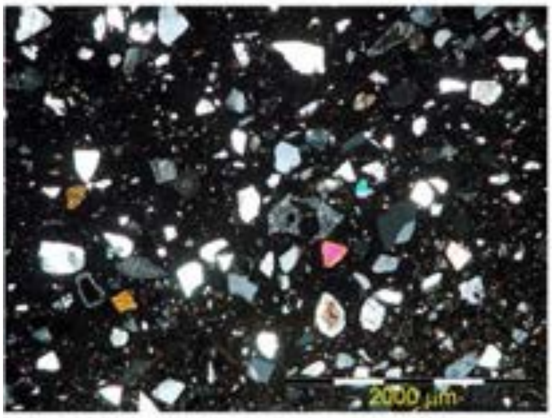
Figure 9



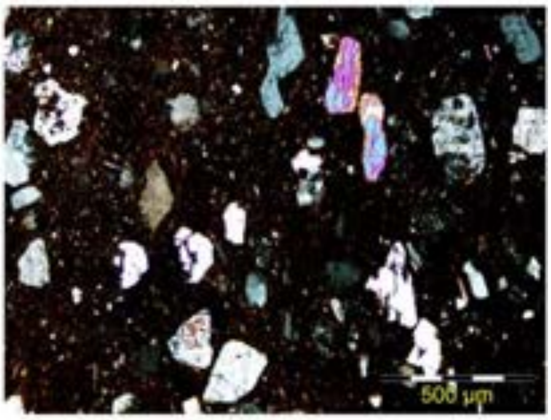
a) PV4022 (D1) 100x XPL



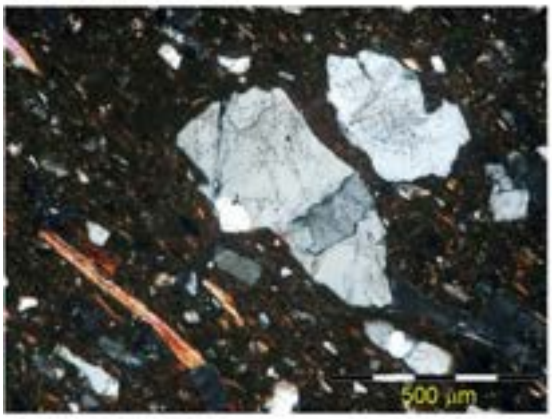
b) PV4017 (D1) 100x XPL



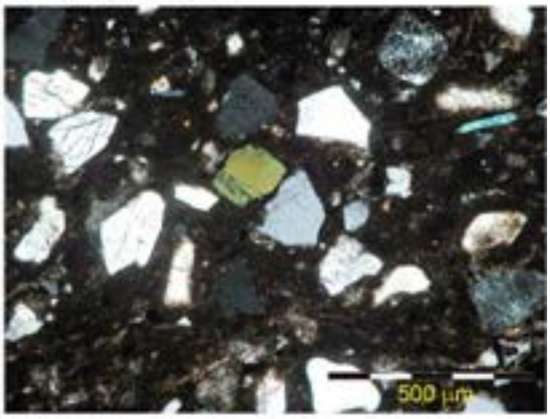
c) PV4037 (D1) 40x XPL



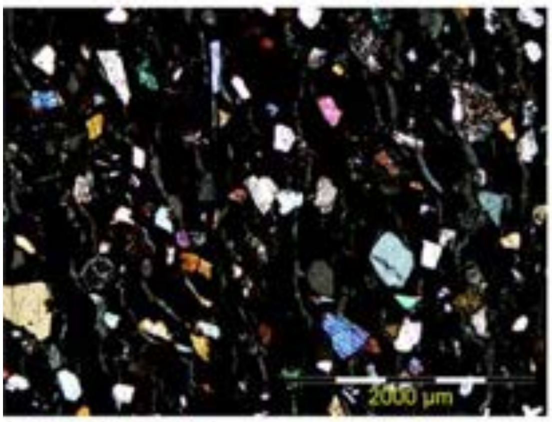
d) PV4021 (D1) 100x XPL



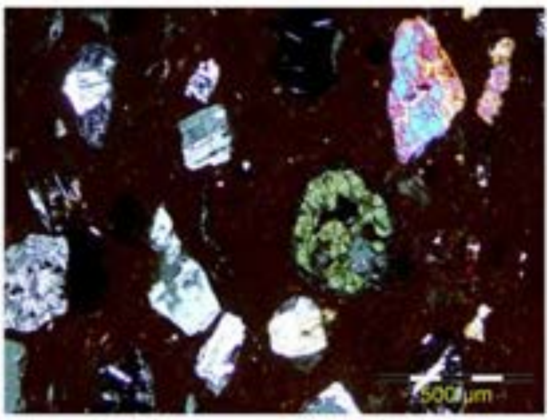
e) PV4033 (D1) 100x XPL



f) PV4032 (L2) 100x XPL

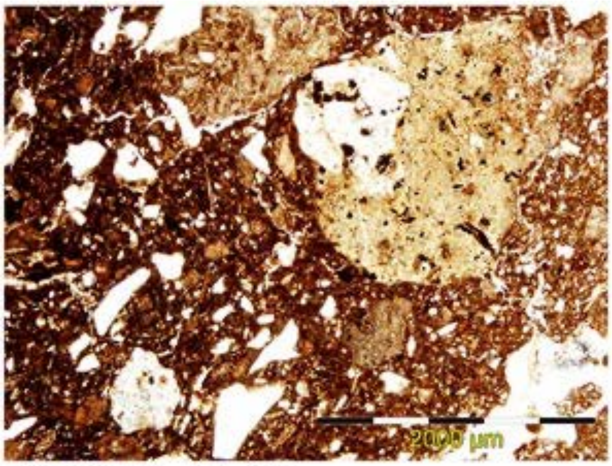


g) PV4029 (L2) 40x XPL

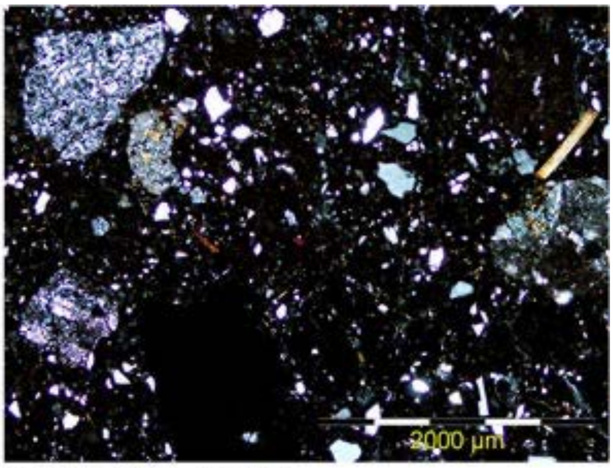


h) PV4027 (L2) 100x XPL

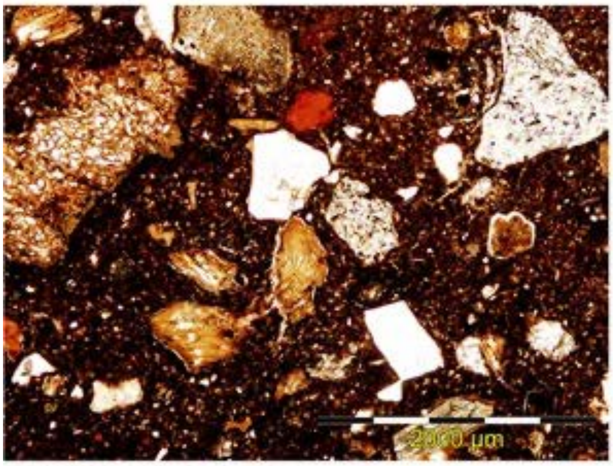
Figure 10



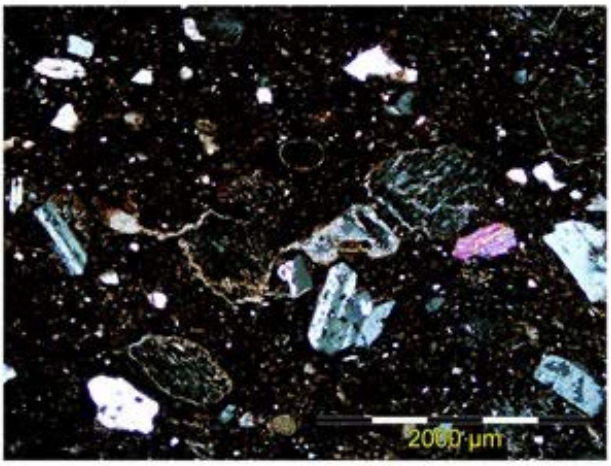
a) PV4019 (*dolium*) 40x PPL



b) PV4019 (*dolium*) 40x XPL

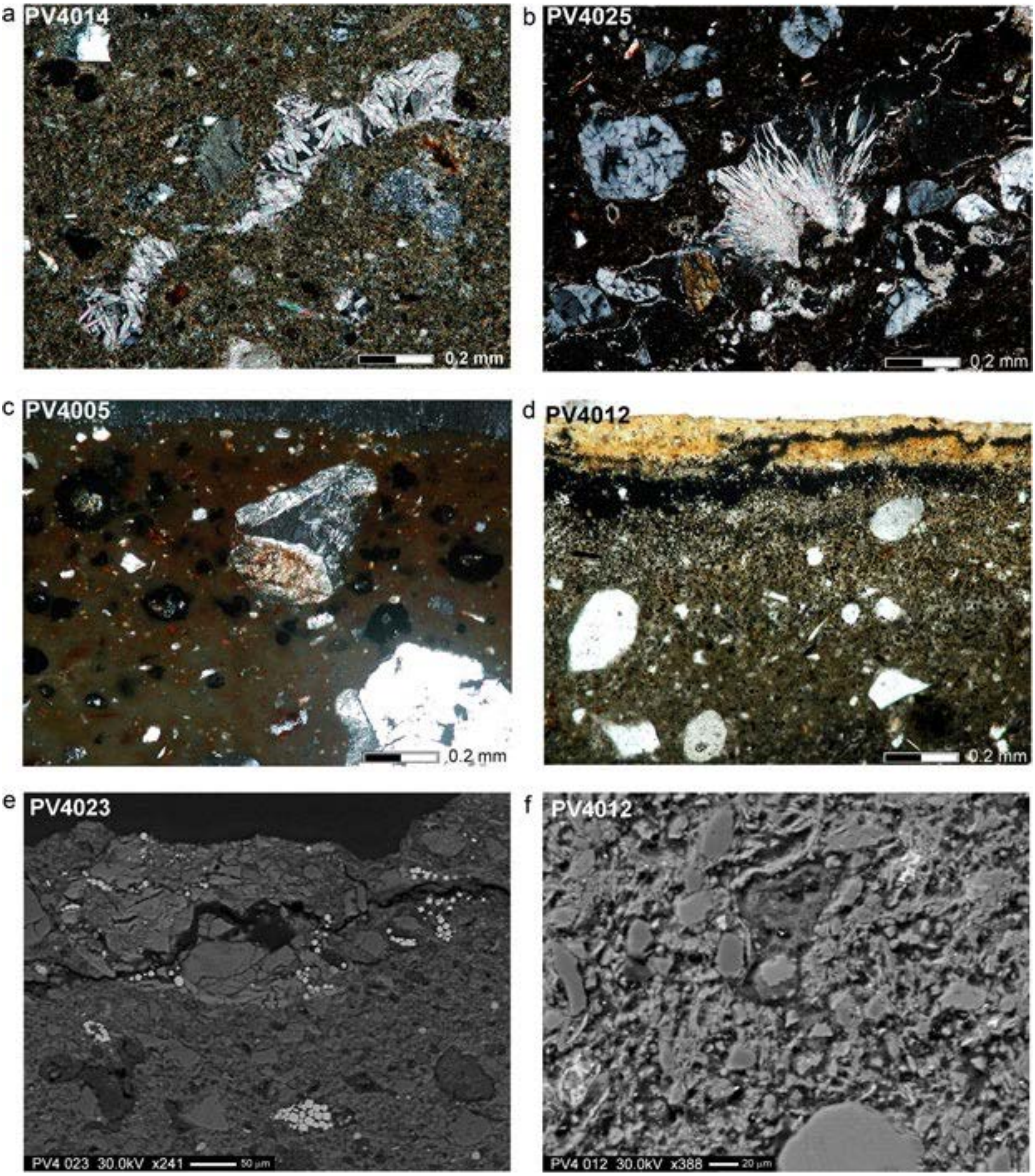


c) PV4020 (*dolium*) 40x PPL



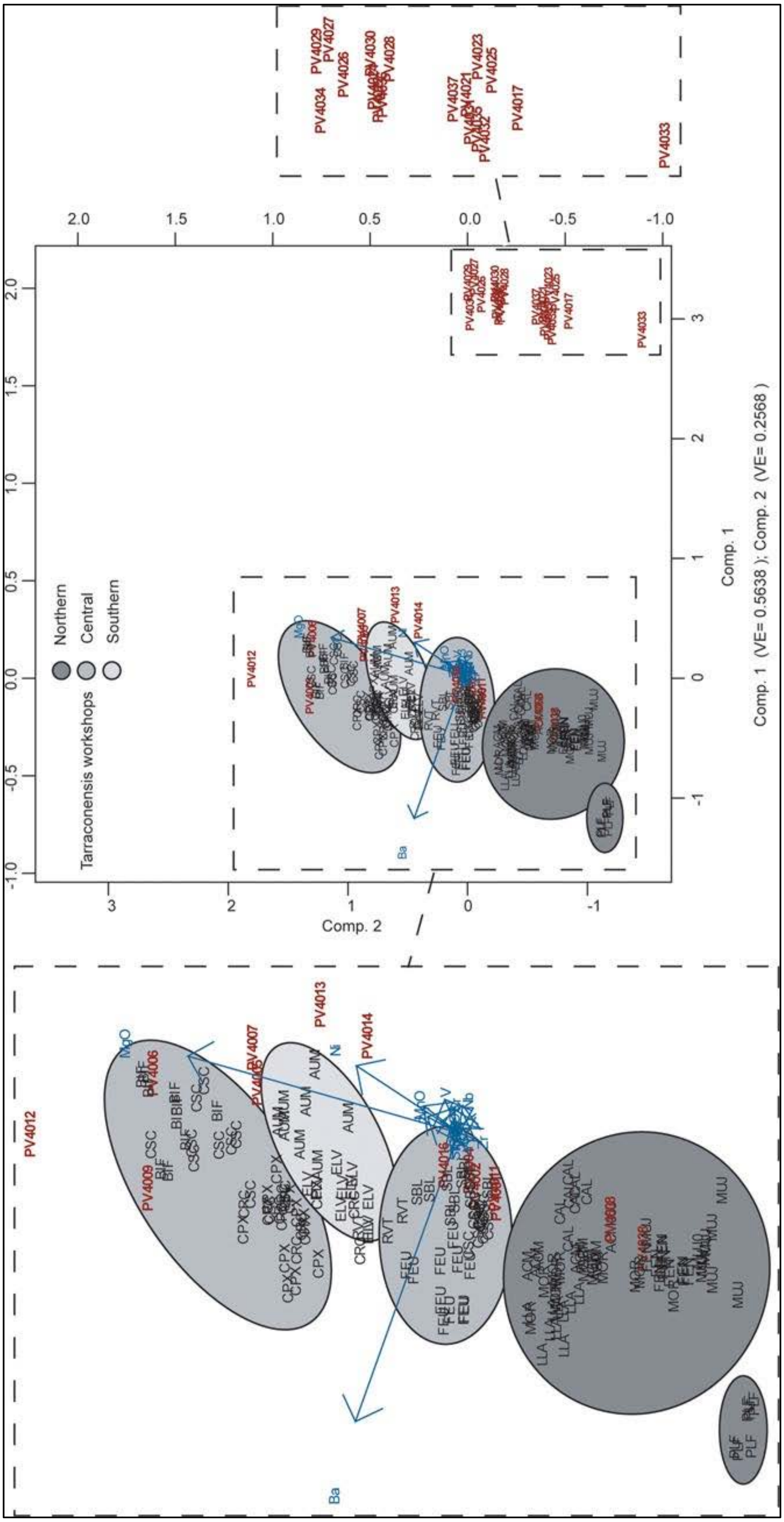
d) PV4020 (*dolium*) 40x XPL

Figure 11



a PV4014
0.2 mm
b PV4025
0.2 mm
c PV4005
0.2 mm
d PV4012
0.2 mm
e PV4023
PV4 023 30.0kV x241 50 µm
f PV4012
PV4 012 30.0kV x388 20 µm

Figure 12


Tarraconensis workshops
Northern
Central
Southern
Comp. 1
Comp. 2
Comp. 1 (VE= 0.5638); Comp. 2 (VE= 0.2568)
PV4012
PV4013
PV4014
PV4033
PV4017
Ba
MgO

SAMPLE	Archaeol. code	Typology	Paste colour	Stamp	Analytical techniques
PV4001	PV-93-4-60	Pascual 1	Reddish	–	XRF, XRD, OM
PV4002	PV-93-4-28	Pascual 1	Reddish	–	XRF, XRD, OM
PV4003	PV-93-4-65	Pascual 1	Reddish	–	OM
PV4004	PV-93-4-64	Pascual 1	Reddish	–	XRF, XRD, OM
PV4005	PV-93-4-10 & PV-93-4-3	Pascual 1	Yellowish	–	XRF, XRD, OM
PV4006	PV-93-4-4	Pascual 1	Brown-reddish	–	XRF, XRD, OM
PV4007	PV-93-4-11 & PV-93-4-2	Pascual 1	Yellowish	–	XRF, XRD, OM
PV4008	PV-93-4-30	Bottom Pascual 1	Reddish	AM	XRF, XRD, OM
PV4009	PV-93-4-12	Pascual 1	Brown-clear	–	XRF, XRD, OM
PV4010	AB-0618-61	Pascual 1	Reddish	–	OM
PV4011	PV-93-4-165	Pascual 1	Brown-reddish	–	XRF, XRD, OM
PV4012	NI 2	Pascual 1	Yellowish-grey	–	XRF, XRD, OM, MEB
PV4013	PV-90-32	Pascual 1	Grey	–	XRF, XRD, OM
PV4014	PV-90-17	Pascual 1	Grey	–	XRF, XRD, OM
PV4015	PV-90-18	Bottom Pascual 1	Reddish	S	OM
PV4016	PV-93-4-16	Bottom Pascual 1	Reddish	TH - S	XRF, XRD, OM
PV4017	AB06-282-71	Dressel 1B	Brown-reddish	–	XRF, XRD, OM
PV4019	PV-93-4-27	Dolium with lead device	Brown-reddish	ΔΙΨΩ	OM
PV4020	PV-93-4-176	*Dolium*	Brown-reddish	–	OM
PV4021	AB-07-115-70	Dressel 1B	Brown-reddish	–	XRF, XRD, OM
PV4022	AB-07-116-70	Dressel 1B	Brown-grey	–	XRF, XRD, OM
PV4023	AB-07-841-75	Dressel 1B	Brown-grey	–	XRF, XRD, OM, MEB
PV4024	AB-07-992-73	Dressel 1B	Brown-grey	–	XRF, XRD, OM
PV4025	AB-07-1050-72	Dressel 1B	Brown-grey	–	XRF, XRD, OM
PV4026	AB-07-82-73	Lamboglia 2	Brown-rose	–	XRF, XRD, OM
PV4027	AB-07-347-71	Lamboglia 2	Brown-rose	M.LOLLIQ.F	XRF, XRD, OM
PV4028	AB-07-618-73	Lamboglia 2	Brown-rose	–	XRF, XRD, OM
PV4029	AB-07-637-73	Lamboglia 2	Brown-rose	–	XRF, XRD, OM
PV4030	AB-07-1011-73	Lamboglia 2	Brown-rose	–	XRF, XRD, OM
PV4031	AB-06-119-66	Lamboglia 2	Brown-rose	–	XRF, XRD, OM
PV4032	AB-06-390-71	Lamboglia 2	Brown-rose	–	XRF, XRD, OM
PV4033	AB-06-79-62	Dressel 1?	Brown-reddish	–	XRF, XRD, OM
PV4034	AB-06-137-71	Dressel 1B	Brown-grey	–	XRF, XRD, OM
PV4035	AB-06-165-67	Dressel 1B	Brown-rose	–	XRF, XRD, OM
PV4036	AB-07-116-70	Dressel 1B	Brown clear	–	XRF, XRD, OM
PV4037	AB-07-847-75	Dressel 1B	Brown-rose	–	XRF, XRD, OM
PV4038	PV-03-4-17	Bottom Pascual 1	Reddish	CHR	XRF, XRD, OM
PV4039	PV-93-4-25	Dolium with lead device	Brown-reddish	ΔΙΨΩ	OM

Table 1

	Samples (PV4)	V. S.	C. M.	% f.f	% c.f.	c.f. size (mm)	c.f. composition
P1-A	1, 4 2 3, 10, 11, 15, 16	** * ***	Fe	****	**	< 1.5	**** (Meta-) Grnt, Qtz Kfs, Pl *** Bt, Ms, Fer ** Ep, Am, Sst / * Qtz-Micsch, Cal (micr)
P1-B	38	***	Fe	****	**	< 1	**** (Meta-) Grnt *** Qtz, Pl, Kfs ** Bt, Ms, Fer / * Qtz-Micsch
P1-C	8	*	Fe	***	***	< 1.5	**** Kfs, Qtz, (meta-) Grnt, Pl *** Fer ** Bt, Ms, Ep, Am / * Ca-microfos
P1-D	6	***	Fe+Ca	***	**	< 0.5	**** Qtz, Ca-microfos *** Qtz-Micsch ** Pl, Kfs, Cht / * Bt, Ms, Fer
P1-E	12	***	Ca	**	**	< 1.5	**** Qtz, Kfs, Pl, Grnt *** Qtz-Micsch ** Cal (micrite), Qtzt, Cht / * Ms, Fer
P1-F	5, 7	****	Ca	**	**	< 1	****Grnt, Qtz, Pl, Kfs *** Bt, Fer ** Ca-microfos / * Ms, Qtzt, Sst
P1-G	9	****	Ca	***	***	< 1.5	****Grnt, Qtz *** Kfs, Pl ** Ca-microfos, Fer / * Bt, Ms, Gns
P1-H	13, 14	*	Ca	**	***	< 0.5	**** Qtz, Qtz-Micsch ***Grt, Kfs, Pl ** Cal (sparite), Ca-microfos / * Bt, Ms, Fer
D1A	22, 36	****	Ca	*	***	< 0.4	**** Cpx, Ol, Bas, Trach *** Qtz, Ca-microfos, Fer ** Sa, Pl / * Am
D1B	17	****	Fe+Ca	***	**	< 0.4	**** Qtz, Cpx, Sa, Bas, Trach *** Mel-Grt ** Ca-microfos, Bt, Cht / * Fer
D1C	21, 24 23, 37 25, 35	** *** ****	Fe+Ca	*	***	< 0.4	**** Qtz, Ls, Ca-microfos *** Ms, Cht, Radiol. ** Cpx, Pl, Kfs, Am / * Srp, Bas
D1D	33	****	Fe	***	***	0.5/1.5	**** Gns, Qtz-Micsch *** Qtz, Kfs, Ms ** Cht, Radiol, Sst / * Fer
L2A	31 32	*** ****	Fe+Ca	*	***	< 0.5	**** Qtz, Pl, Kfs *** Sa, Cht, Radiol., Ls, Ca-microfos ** Cpx, Ms / * Bas
L2B	26, 27 29, 30 28	* ** ****	Fe+Ca	-	****	< 0.5	**** Bas, Cpx, Ol, Trach *** Qtz, Pl, Sa, Fer ** Am / * Cal (micrite)
DOL1	19, 39	**	Fe	***	***	< 4	**** Qtz, Cpx, Rhyol *** Bas, Cht, Radiol., Ms ** Kfs, Pl, Ol / * Cal (micrite), Fer
DOL2	20	**	Fe+Ca	**	***	< 3	**** Qtz, Cpx, Sa *** Volc-glass, Bas, Trach ** Ca-microfos, Bt, Ol, Srp, Cht / * Fer

Table 2

Sherds	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	LOI
PV4001	7.7	17.9	0.11	0.16	1.03	2.25	3.3	1.77	3.07	62.6	552	137	21	22	26	263	48	144	92	22	129	109	18	20	70	1.47
PV4002	8.4	18.4	0.11	0.16	1.11	2.37	2.6	1.68	3.20	61.8	567	146	23	24	28	277	50	141	99	24	139	122	18	25	59	1.83
PV4004	8.1	18.5	0.11	0.17	1.07	2.67	3.2	1.71	3.08	61.2	530	140	25	23	26	268	50	150	107	23	133	117	18	22	64	2.50
PV4005	5.9	16.0	0.06	0.13	0.65	6.11	12.4	2.50	1.79	54.2	405	66	15	16	19	161	25	298	59	19	79	74	33	32	62	1.93
PV4006	6.3	16.8	0.08	0.13	0.79	8.69	7.3	1.54	2.28	55.9	500	83	15	19	29	201	32	214	88	20	105	111	32	38	77	6.53
PV4007	5.7	15.8	0.07	0.12	0.65	6.36	13.3	2.99	1.45	53.4	349	58	15	16	21	162	25	292	63	18	75	76	29	31	60	2.07
PV4008	6.4	18.1	0.07	0.13	0.80	1.45	1.5	2.15	3.65	65.6	506	118	19	18	22	278	39	126	104	20	103	80	16	23	68	3.09
PV4009	4.9	14.9	0.08	0.14	0.62	7.48	10.0	1.84	3.30	56.5	685	105	14	17	24	200	26	187	68	17	82	71	28	28	67	5.96
PV4011	7.8	18.0	0.11	0.15	1.03	2.25	3.5	1.62	3.11	62.3	538	144	23	22	26	239	47	138	117	23	131	112	18	21	69	1.47
PV4012	5.1	14.9	0.09	0.14	0.68	12.20	6.2	1.70	1.81	57.0	661	59	14	16	18	169	27	199	67	19	110	93	26	30	77	9.19
PV4013	5.3	15.1	0.06	0.19	0.64	3.51	13.3	1.39	2.79	57.6	295	112	14	16	24	144	28	290	59	16	100	90	27	56	88	12.76
PV4014	5.2	14.5	0.07	0.22	0.60	2.53	14.0	1.41	2.74	58.6	309	112	12	16	24	141	29	303	68	15	90	88	28	54	86	12.82
PV4016	7.7	18.2	0.11	0.15	1.03	2.90	3.6	2.04	2.95	61.1	518	131	22	22	27	263	47	153	102	23	119	114	21	24	61	2.30
PV4017	5.8	17.8	0.12	0.14	0.72	2.95	6.3	1.77	3.26	61.0	468	164	19	33	32	264	34	272	106	21	109	99	26	36	76	4.42
PV4021	6.0	16.9	0.07	0.15	0.72	3.30	8.9	1.09	2.55	60.2	298	139	18	23	37	205	26	379	98	20	126	96	32	44	93	5.12
PV4022	6.7	16.1	0.11	0.35	0.77	4.17	11.9	1.91	3.24	54.5	602	139	21	29	52	233	28	500	83	19	124	103	26	44	87	6.43
PV5023	6.0	15.6	0.08	0.15	0.69	2.90	9.5	1.18	2.55	61.2	342	133	15	23	36	203	25	345	81	18	122	98	30	42	105	6.26
PV4024	6.1	16.7	0.08	0.14	0.76	4.68	6.87	1.02	2.13	53.45	263	113	20	24	37	215	29	249	95	19	139	97	32	47	98	5.83
PV4025	6.1	16.4	0.08	0.15	0.72	2.83	9.1	1.29	2.54	60.7	319	137	16	24	33	206	24	332	96	19	122	98	32	43	100	4.46
PV5026	8.4	18.0	0.16	0.33	0.92	4.48	10.2	1.72	2.86	52.7	576	144	24	32	34	223	32	427	96	23	167	126	47	68	118	2.56
PV5027	8.3	17.8	0.14	0.35	0.90	5.16	11.3	1.79	2.61	51.3	611	120	20	31	34	218	31	430	83	22	153	121	44	67	121	1.83
PV4028	8.0	18.0	0.14	0.36	0.88	4.23	10.6	1.96	2.89	52.7	710	132	20	32	31	221	30	477	78	22	141	114	42	59	108	0.53
PV5029	8.6	16.9	0.15	0.39	0.93	4.98	11.3	1.82	2.81	51.9	706	127	21	33	36	228	30	485	100	21	169	114	41	60	124	0.77
PV5030	8.0	17.7	0.14	0.38	0.88	4.43	10.7	1.82	3.00	52.7	767	135	20	32	36	222	30	494	89	22	157	117	42	58	114	0.80
PV4031	5.8	16.6	0.08	0.17	0.68	3.14	9.8	1.30	2.55	59.8	291	119	19	21	30	186	22	308	55	17	119	93	27	41	93	7.40
PV4032	5.8	16.1	0.07	0.15	0.68	2.89	7.3	1.21	2.46	63.2	345	107	20	20	28	194	22	270	70	17	111	84	25	38	92	4.20
PV4033	5.2	16.5	0.06	0.07	0.72	1.62	3.0	1.09	2.44	69.2	253	109	15	14	27	191	20	136	61	17	95	66	22	30	101	2.33
PV4034	4.9	13.4	0.07	0.18	0.56	4.51	12.4	1.36	2.58	59.9	319	97	18	16	26	175	25	327	62	14	102	78	16	38	91	11.16
PV4035	5.8	16.8	0.07	0.15	0.69	3.14	9.4	1.29	2.49	60.1	304	127	20	20	30	179	23	295	70	18	112	89	27	41	91	4.57
PV4036	6.9	16.0	0.11	0.34	0.77	3.97	11.1	2.02	3.28	55.3	543	132	20	28	36	223	27	467	84	17	130	104	28	46	87	6.17
PV4037	5.8	15.6	0.08	0.14	0.66	3.26	9.4	1.13	2.50	61.2	304	117	17	19	32	183	22	300	64	16	118	90	27	38	93	7.06
PV4038	6.7	19.1	0.08	0.11	0.92	1.57	1.5	2.07	3.06	64.8	535	129	23	19	30	273	36	135	110	22	109	102	21	14	50	1.63

Table 3