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Inès Pactat [a], André Constant [b], Nadine Schibille [a,*]

[a] IRAMAT-CEB, UMR5060, CNRS/Université d'Orléans, 3D Rue de la Férollerie, 45071 Orléans, France
[b] LA3M, UMR 7298, CNRS/Aix-Marseille Université, MMSH, 5 Rue du Château de l'Horloge, 13094 Aix-en-Provence, France

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ABSTRACT

Founded in the fifth century on a granite outcrop overlooking the deep valleys of the eastern Massif des Albères and the Roussillon coast, the hilltop settlement of Ultrera/Ultrère was strategically located to dominate the lowlands. Its position on this natural boundary between the Iberian Peninsula and Central Europe raises interesting questions about its connectivity and the circulation of materials. In the early days of rural feudalism, the emergence of the *castrum* led to the birth of the "feudal" castle and the first fortified villages. Ultrera was organized into several districts spread over three hectares and survived until the tenth century CE, which is an exceptionally long occupation. The present paper examines the glass supply to Ultrera throughout its history, combining typological and archaeometric approaches to study the evolution of glass compositions and the use of different raw materials through time. A series of 43 well-contextualized glass objects have been analysed for major, minor and trace elements using LA-ICP-MS. The glasses of the fifth to seventh centuries comprise mostly vessels and especially goblets. The base glass can be affiliated to previously established natron-type primary production groups (HIMT, Foy 2.1, Foy 3.2 and Levantine 1), and about half of it shows substantial signs of recycling. The ninth- to tenth-century assemblage marks a change from the previous occupation. Two beads made from a soda-rich plant ash glass confirm Islamic imports from Mesopotamia and perhaps the western Mediterranean. A linen smoother with a wood ash glass signature is the only testimony of Carolingian influences. Glass tableware is becoming increasingly rare and some of the drinking goblets are remnants from a previous phase. The progressive independence of the Catalan counties from the Carolingian Empire and the change of the glass production system towards the end of the first millennium CE may explain the absence of typical Frankish glass. Soda plant ash glass from the thirteenth and fourteenth centuries, probably from the feudal castle, indicates yet another change at the end of the Middle Ages, when there is evidence for both regional production and long distance imports.

1. Introduction

The supply of glass across the late antique and early medieval world relied on imports from the primary glass production centres located along the Levantine coast and in Egypt (Brill, 1988; Foy et al., 2003; Freestone et al., 2000). The transformation of the social and geopolitical landscape in the second half of the first millennium CE resulted in changing consumption patterns of glass in the western Mediterranean region (De Juan Ares et al., 2019a; Foy et al., 2003; Maltoni et al., 2018), and eventually the cessation of eastern imports and the development of regional glassmaking traditions (Gratuze et al., 2014; Pactat et al., 2017; Schibille et al., 2020). While this phenomenon has been intensively studied in relation to the Italian (Bertini et al., 2020; Uboldi and Verità, 2003) and Iberian Peninsulas (De Juan Ares and Schibille, 2017; De Juan Ares et al., 2018; De Juan Ares et al., 2021) as well as central and northern Europe (Pactat et al., 2017; Van Wersch et al., 2016; Wedepohl et al., 1997), the south of modern-day France has not yet attracted the same level of interest. The present article focuses on the typology and the chemical characteristics of the glass finds from Ultrera/Ultrère in the eastern part of the Pyrenees in order to assess the consumption profile over time in light of the geopolitical and economic context of this hilltop settlement, and to explore to what extent it was part of a regional network of glass supplies during the early medieval period.

* Corresponding author.
E-mail address: nadine.schibille@cnrs-orleans.fr (N. Schibille).

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2. Archaeological context

Erected on a 400 to 500 m high granite summit, the *castrum* of Ultrera/Ultrère near Argelès-sur-Mer in the Pyrénées-Orientales shows all the constraints and advantages of a medieval hilltop settlement. Close to the current French-Spanish border, it overlooks the valleys of the Albera Massif and the entire Roussillon plain and coastline (Fig. 1). Its advantageous location is echoed in the seventh-century writings of Julian, archbishop of Toledo, who describes Ultrera as *Vulturaria* which literally means "area of the vultures" (Basseda, 1990, 693-694). The barren landscape with its gneiss and dense xerophilous vegetation makes the choice of this location all the more surprising, no doubt the result of a desire to control and dominate the immediate surroundings and the coastal lowlands. Archaeological prospections in the 1990s and ten seasons of excavations from 2000 (Constant et al., 2018) make the *castrum Vulturarium* one of the very rare examples of grouped hilltop settlements of the Early Middle Ages excavated in the Western Mediterranean. A total of 1,200 m^2 of buildings and various remains have been investigated (Fig. 2). Thanks to the architectural and stratigraphic data, the evolution and functions of the different parts of the *castrum* can now be fully reconstructed. Three chronological phases have been firmly established. Following an *oppidum* of the Late Bronze Age IIIb (Phase 1), a significant repopulation of the entire Pic Saint-Michel takes place from the second half of the fifth century CE. It is characterised by the creation of platforms for residential areas. The settlement of Ultrera thus illustrates in a way a more global process of hilltop developments at the beginning of the Middle Ages, which is now widely documented in France and throughout Western Europe. A rare feature is that the occupation in Ultrera/Ultrère continued in several sequences until the end of the tenth century CE (Table 1). There is nothing to indicate that the *castrum* of Ultrera was a small fort or citadel from the beginning, as was assumed in the past. Although the strategic aspect may seem obvious due to the topography of the site, it was a rather spontaneous occupation of the *saltus* (uncultivated lands) in the fifth to sixth centuries, followed by the emergence of a polynuclear complex in the seventh to eighth centuries, and then by a *castellum* (*roca* castle) in the ninth to tenth centuries (Constant, 2007; Constant, 2020; Constant et al., 2018).

3. Materials and methods

3.1. Glass samples

118 glass fragments have been unearthed during archaeological excavations since 2000, representing at least 48 individual objects, of which 43 samples were selected for compositional analyses (Table S1). The glass samples under investigation include different vessels as well as beads and a linen smoother and come from stratigraphic contexts that can be linked to one of the two medieval phases and their sub-sequences (Fig. 3). Only one sample belongs to the first stage of the early medieval occupation (phase 2a), dated to the mid-fifth to mid-sixth century CE. 14 samples are associated with phase 2b (mid-sixth to early eighth century CE), while 21 fragments come from the second medieval occupation levels (phases 3a/b/c, end of the eighth to the mid-tenth century CE). Nine analysed glass fragments were discovered in the final abandonment and destruction levels that may have been occasionally frequented during the following centuries, in connection with the feudal castle of Ultrera (phase 4).

Among the vessels, the earliest element is a cold-cut rim of a goblet or a cup in olive green glass (7003-9) which has numerous parallels around the Mediterranean from the end of the fourth to the early sixth century CE (Foy, 1995, 198-199). The typological attribution of the other rims is constrained by the fragmentary nature and the relative commonality of the rounded rims across the early medieval corpus. They may belong to palm cups (e.g. 6002-23, 6005-24, 6028-27, 6069-36 or 6080-39; Fig. 3), but the presence of stems suggests that some of the rims are connected to wine glasses (e.g. 1012-1). Indeed, three fragments of stems and one of a discoidal foot demonstrate the use of solid stemmed wine glasses. Three of them (1057-18, 6077-37 and 6080-42) are attributed to the mid-sixth to eighth century CE, while one (1049-17) comes from the construction level of a kitchen, dating to the eighth to ninth century. One stem (6000-19) was recovered at a surface level corresponding to the destruction and the abandonment of the site.

Hollow stemmed glasses with a folded and pushed-in foot represent an earlier type of wine glass. Unfortunately, the fragmentation of the samples 6034-29, 6044-32 and 7004-10 does not allow a clear identification of the exact forms of these goblets. The latter comes from a level dated to the seventh to eighth century CE, while the other two were discovered in the late occupation layers (phase 3c).

Several blue-green body and base fragments (6035-28 and 6035-30) have a facet-moulded decoration which consists of radiant moulded ribs on the base and a honeycomb pattern on the body. No fragment of rim or neck has been recovered, but this kind of ornament and the shape of the globular body suggest a bottle or a flask. The archaeological context proposes a dating after the abandonment of the site, i.e. after the tenth century CE, but it remains relatively imprecise.

The rest of the analysed vessels are body sherds without any distinctive typological features, but they were included in the selection for their colours such as pale blue with red trails (6028-26), cobalt blue (8001-40) and amber (8002-41, 8003-46, 8004-48 and 8013-50). The

Fig. 1. Location of Ultrera in context of the main early medieval sites in the Eastern Pyrenees (left); aerial view of the remains of the castle of Ultrera/Ultrère (11^{th}-17^{th} century CE) that succeeded the ancient *castrum* (5^{th}-10^{th} century CE), situated below the castle (right, photo Edikom).

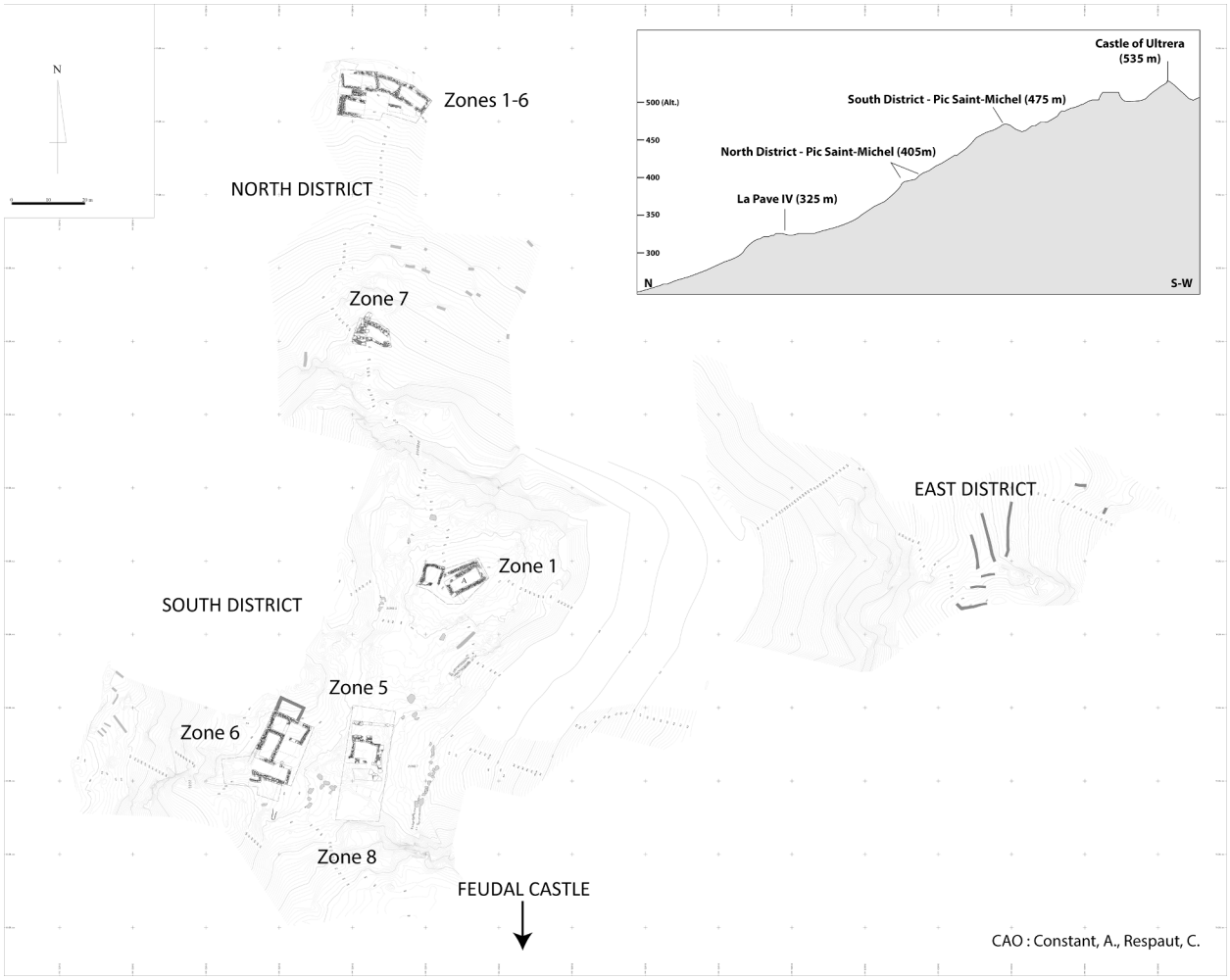

Fig. 2. Location of the different districts of the site of Ultrera.

Table 1
Different stratigraphic phases identified at Ultrera/Ultrère and archaeological characteristics.

Phase	Date	Features
Phase 2a	5th–6th c.	spontaneous hilltop development and occupation of the Pic Saint-Michel, buildings made of perishable materials
Phase 2b	7th–8th c.	appearance of a polynuclear settlement organised in several terraced districts (south and north) and covering an area of at least 3 ha
Phase 3a-b-c	late 8th–10th c.	emergence of a first castle prototype (*Roca*) on the summit of Pic Saint-Michel (South District), abandoned around 1000 CE. This small fortress consists of several buildings including a tower, and occupies an exceptionally large surface (4,500 m^2) compared to other known examples in southern France
Phase 4	11th c. onwards	following the abandonment of the old *castrum*, very sporadic building demolitions and traces of frequentation associated with the feudal castle of Ultrera, founded only 250 m to the south

corpus includes also three beads. An olive green melon bead (6028-25) is dated on archaeological grounds between the sixth and the eighth century CE. A black spherical bead with white trails (4000-3) and a fusiform and mandrel-formed cobalt blue bead (4000-4) were discovered in a destruction level in the North District of the Pic Saint-Michel, dating from the ninth to tenth centuries CE.

The last glass analysed is a fragment of a corroded black linen smoother (6054-34). This typical Carolingian object was found in a construction phase of a ninth- to tenth- century building in the South District (phase 3b).

3.2. Analytical method

The archaeological material was not sampled to preserve the integrity of the glass objects. Single-point analyses were performed on the well-preserved surface or on the cross-section of the sample by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) at the Centre Ernest-Babelon of IRAMAT (Orléans) using a Thermofisher Element XR combined with a Resonetic UV laser microprobe (ArF 193 nm) (following the protocol of Gratuze, 2016). This method was chosen for its minimal destructiveness, since the laser beam diameter ranges from 40 to 100 μm and its depth is around 250 μm. LA-ICP-MS is also suitable to analyse composite objects, like the black and white bead 4000-3, because it can provide distinctive results for each part of the sample.

The laser was operated at 5 mJ with a pulse frequency of 10 Hz. 20 s pre-ablation time was followed by 30 s collection time. Blanks were run every twelve samples to determine the offset. Using LA-ICP-MS, 58 elements are measured and quantified. They represent the major and minor constituents of glass that allow us to identify the raw materials and the recipes, most of the chromogenic agents and their associated impurities, as well as a large number of trace elements used to determine the glass provenance. The signals are converted into quantitative data by calculating a response coefficient (K_y), using a set of five glass standards

Fig. 3. Drawings and photos of the glass objects from Ultrera analysed by LA-ICP-MS.

(NIST SRM610, Corning B, C, D and APL1, an in-house standard). Corning A and NIST SRM612 glass standards are systematically measured to ascertain the precision and accuracy of the measurements (Table S2).

4. Results and discussion

Three main compositional groups can be distinguished: soda-rich plant ash glass, wood ash glass and natron-type glass (Fig. 4,

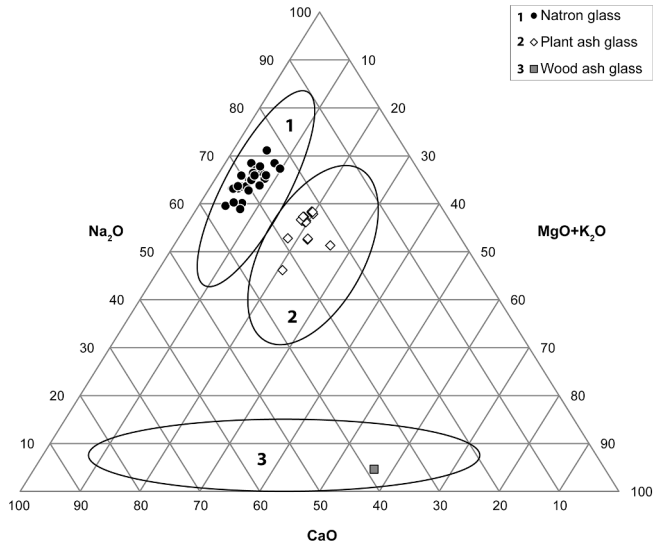

Fig. 4. Ternary diagram distinguishing the fluxing agent.

Table S1), the latter representing the largest group (n = 27).

4.1. Compositional groups

4.1.1. Natron-type glass

Twenty-seven glass vessels or lamps and a melon bead are soda-lime-silica glasses. These natron-type glasses have low potassium and magnesium oxides levels (<1.5%), but differ in terms of the silica sources and their production process. Based on the ratios of titanium to aluminium and aluminium to silica, which reflect the sand source, five different natron-type glasses can be identified: Jalame-type, HIMT, Foy 2.1, Foy 3.2 and Levantine 1(Fig. 5). A single sample (7003-9) from Ultrera exhibits the characteristics of so-called HIMT (*High Iron Manganese Titanium*) glass of Egyptian origin, generally dated to the fourth and fifth centuries CE (Freestone et al., 2018). It differs from the other groups by higher titanium oxide (0.42%), iron oxide (1.42%), zirconium (237 ppm), chromium (59.1 ppm) and hafnium (5.37 ppm) contents and a low level of lime (5.76%) (Table S2). High levels of manganese (here 2.4% MnO) is also a determining factor. Long considered a voluntary addition to reduce the colouring power of impurities naturally present in the sand, the role of manganese in HIMT glass has recently been

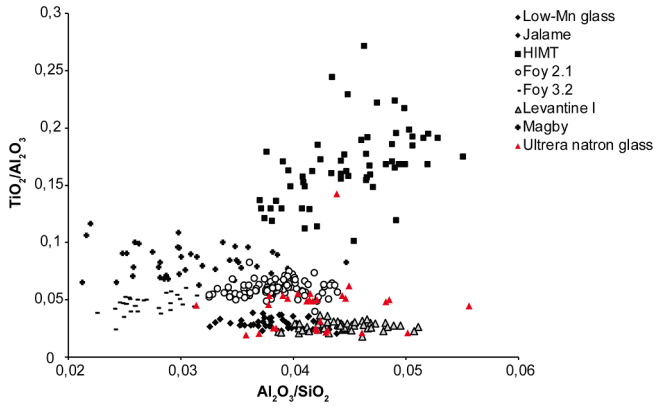

Fig. 5. Comparison of Ultrera natron glass with several primary production groups of the second half of the first millennium CE: low-Mn glass (Jackson and Paynter, 2016), Jalame (Brill, 1988), HIMT (Ceglia et al., 2015; Foy et al., 2003), Foy 2.1 (De Juan Ares et al., 2019a; Foy et al., 2003), Foy 3.2 (Cholakova and Rehren, 2018), Levantine 1 (De Juan Ares et al., 2019a) and Magby (De Juan Ares et al., 2019a; Schibille et al., 2016).

reassessed and it is now assumed that this element was introduced with an iron ore to generate a distinct deep and bright olive green hue (Freestone et al., 2018, 183-184).

Median levels of zirconium (≈89 ppm) and titanium oxide (≈0.15%) of 3007-53, 5008-8, 6028-25, 6034-29, 6069-36 and 7004-10 match group 2.1 of Foy et al. (2003), but the significantly higher iron and vanadium contents of the last four samples (Fig. 6a) identify these glasses as the sub-group Foy 2.1 high Fe (Schibille et al., 2016). Later than HIMT, Foy 2.1 glass (late fifth to early seventh century CE; De Juan Ares et al., 2019a) was made in Egypt as well (Barfod et al., 2020). One sample (6028-27) is characterised by low alumina (2.15%), relatively high silica (68.7%) and manganese as the main decolouring agent. Its titanium oxide (0.10%) and zirconium (65.6 ppm) levels are a little higher than of those of Levantine glasses (TiO_2≈0.07% and Zr≈41 ppm) and lower than the Foy 2.1 group. In this it coincides with another possibly Egyptian glass group so-called Foy 3.2 (Foy et al., 2003). Foy 3.2 is attested in the western Mediterranean (Foy et al., 2003), in Italy (Gallo et al., 2014; Maltoni et al., 2015), the Balkans (Milavec and Šmit, 2020) and Bulgaria (Cholakova and Rehren, 2018) from the late fourth to the early sixth century CE. A recent study has proposed that a large amount of Foy 3.2 glass may have been remelted and mixed with sand and natron to produce Foy 2.1 glass, which could explain the frequent compositional overlap of the two groups (Cholakova and Rehren, 2018).

The rest of the samples have low contents of titanium and zirconium oxides, demonstrating the use of a silica source poor in heavy minerals (Fig. 5). The sands of the Levantine coast are known to provide such a raw material. Two naturally coloured glass samples (6001-20 and 6035-31) can be attributed to the Roman period and the low-Mn group (Jackson and Paynter, 2016). This blue-green or aqua coloured raw glass is one of the most widespread groups from the first to the fourth century CE and is thought to have been produced in Syria-Palestine (Brill, 1988; Foy et al., 2000; Jackson and Paynter, 2016). Finally, four natron glasses (1057-18, 6080-39, 4000-5 and 7008-13) that have no manganese (<0.05% MnO), high alumina (≈3.2%) and lime (≈8.1%) concentrations, and low heavy minerals are consistent with later Levantine primary productions (Fig. 7). Based on the concentrations of lime and alumina, a distinction can be made between the productions of Jalame (fourth century CE), Apollonia (sixth to seventh century CE) and Bet Eli'ezer (eight century CE). While sample 6080-39 may belong to the Jalame group, samples 1057-18, 4000-5 and 7008-13 are closer to Apollonia-type Levantine 1 (Freestone et al., 2008; Phelps et al., 2016; Tal et al., 2004).

All of the natron glasses of Ultrera are naturally coloured, ranging from pale blue to olive green. Colouring and opacifying agents have therefore not been intentionally introduced into the batches to produce and decorate these glasses, with the possible exception of the HIMT sample (see above). In some cases, however, the levels of colouring elements such as lead, tin, antimony or copper oxides are higher than what one would expect from a mixture of sand and natron. In fact, antimony is usually negligible in most silica sources (Sb < 1.4 ppm, Degryse, 2014, 79), and low concentrations of Pb, Sn and Cu (<100 ppm) can also be attributed to the primary raw materials. Colouring and opacifying elements in excess of these background levels are typically related to either a deliberate modification of the material or to recycling (Brems and Degryse, 2014; Paynter and Jackson, 2016). Comparisons of Sb_2O_3 and PbO concentrations highlight different degrees of recycling among the natron-type glass (Fig. 6b). Only ten samples have low Sb, Sn, Pb and Cu contents (<100 ppm), and only the Levantine 1 group is distinguished by the use of very pure raw materials and can be considered pristine. The other glasses show somewhat elevated antimony concentration (5–80 ppm), indicative of the incorporation of cullet at some point during the life cycle of the glass. About half of the natron glass of Ultrera shows substantial signs of recycling. This phenomenon has been widely recognised in glass assemblages in Europe and the western Mediterranean from the seventh century CE onwards (De Juan Ares et al., 2018; De Juan Ares et al., 2019a; Foy et al., 2003; Freestone and Dell'Acqua,

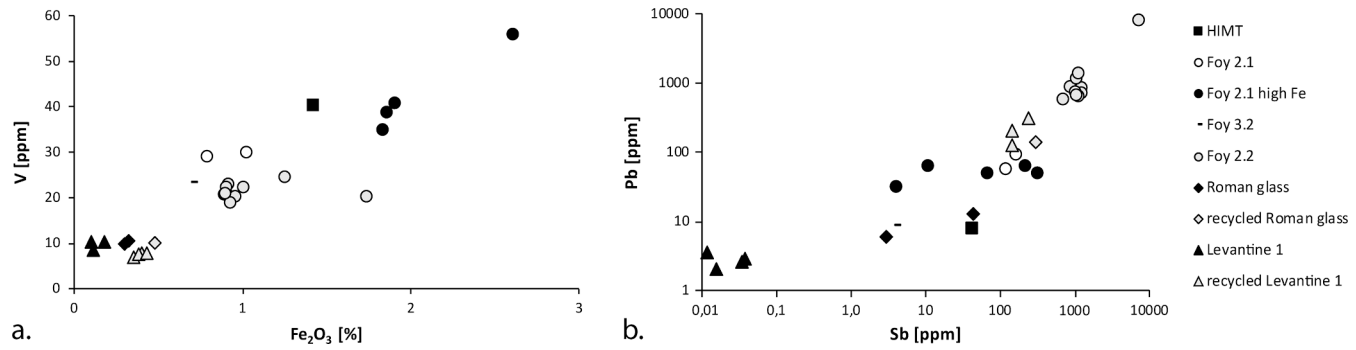

Fig. 6. Characteristics of the natron-type glasses from Ultrera. (a) Correlation between vanadium (V_2O_5) and iron (Fe_2O_3); (b) bi-plot of lead oxide (PbO) versus antimony oxide (Sb_2O_3) showing varying degrees of recycling.

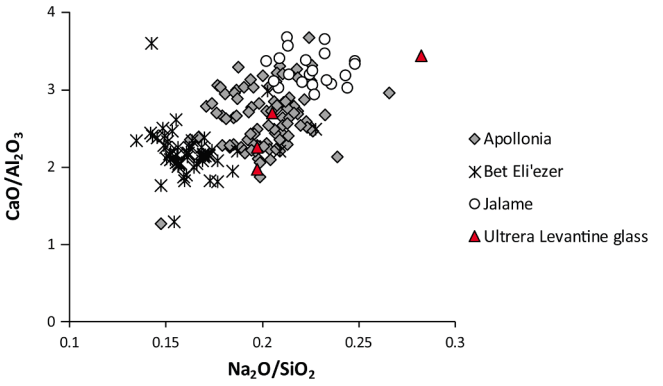

Fig. 7. Distinction of the late Levantine primary productions as a function of lime to alumina ratios and soda to alumina ratios (Brill, 1999; Freestone et al., 2000; Freestone et al., 2015; Phelps et al., 2016).

2002; Mirti et al., 2000; Vichy et al., 2007).

4.1.2. Plant ash glass

15 samples from Ultrera are soda plant ash glasses, characterized by high soda contents and low magnesia and potash levels, but higher than those of natron glass (>1.5%). Two beads (phase 3a/b) and thirteen fragments of vessel glass (phase 4) are concerned. The black and white bead 4000-3 is characterized by a huge amount of alumina (black glass: 6.90% and white glass: 5.36%), correlated with iron and titanium. Comparable features are known from some artefacts from Qsar-es-Seghir, an Islamic port midway between Tangier and Ceuta on the Moroccan shores of the Strait of Gibraltar (Brill, 1999), a bead from al-Basra (Robertshaw et al., 2010) and some high-alumina glass finds from Raqqa (Henderson et al., 2004). Several high-alumina samples have also been found among Venetian glasses from the eleventh to fourteenth century CE (Verità and Zecchin, 2009), but without reaching the levels of sample 4000-3. According to our current state of knowledge, the origin of this high-alumina glass is still unknown. The CoO/ZnO ratio of the blue bead 4000-4 is consistent with early Islamic cobalt ores (Gratuze et al., 2018), and its soda plant ash base is similar to Sasanian and Abbasid glasses from Mesopotamia (Fig. 8; Mirti et al., 2008; Mirti et al., 2009; Henderson et al., 2004).

It is possible to distinguish two types of halophytic plant ash according to the balance between soda, magnesia and potash contents (Fig. 9). A comparison between known or suspected western artefacts from Perpignan, Montpellier and Barcelona dating to the thirteen to fourteenth centuries CE, and those from the Levantine coast from Tyre, Banias and Montfort, shows a clear separation (Fig. 9). The western glasses are on average slightly richer in soda (12–19% Na_2O) than the eastern ones (9–14% Na_2O). Levantine ash was produced in the Near East (Syria, Lebanon) by burning halophytic plants of the species *Salsola soda* (Barkoudah and Henderson, 2006), while in the western Mediterranean, *Barilla* ash is a generic term that includes various species, mainly of the genus *Salsola, Salicornia* and *Chenopodium*. For instance, *Salsola kali*, which is believed to be the main source of western European ash, is richer in potash than other species of the same genus (Tite et al., 2006). The late medieval soda plant ash glasses from Ultrera belong to both groups (Fig. 9): twelve samples of amber and naturally coloured glass vessels (6035-28, 6035-30, 8002-41, 8001-43, 8002-44, 8003-45, 8003-46, 8004-48, 8007-49, 8013-50, 8013-51 and 8022-52) were apparently made with *Barilla* ash in the western Mediterranean, while sample 8001-40 appears to correspond to the Levantine ash group. This cobalt blue glass also corresponds to Levantine plant ash glass in terms of its silica source (Fig. 8). Zinc is correlated with cobalt but the CoO/ZnO ratio (1.82) differs significantly from the average values of early Islamic plant ash glasses (Gratuze et al., 2018). Some thirteenth-century glass finds from the Crusader castle of Montfort in Israel (Wypyski and Pilosi, 2003) has a similar cobalt signatures as well as comparable alkali and alkaline earth concentrations (Fig. 9). The rest of the late medieval plant ash glasses from Ultrera was made with *Barilla* ash, which indicates a western production (Fig. 9). They separate into four tight compositional clusters that appear to represent the same objects, judging from the standard deviations of each sub-group that is within the limits of analytical uncertainty across all elements (Fig. 10). All four sub-groups are compositionally close to thirteenth- to fourteenth-century glasses from Montpellier and Perpignan (France, unpublished data) and contemporaneous stained glass windows from the Santa Maria de Pedralbes presbytery at the royal monastery in Barcelona (Gimeno et al., 2008) (Fig. 9). These are all places of consumption, hence we still do not know where the finished objects were made, although regional workshops are very likely.

4.1.3. Wood ash glass

A single glass object (smoother 6054-34) belongs to the group of wood ash glasses. The high and equivalent contents of lime and potash as well as the low soda concentration are consistent with the use of wood/forest plant ash as alkali source.

4.2. Relationship between typology and composition

4.2.1. The cold-cut rim

The unique HIMT glass found on the hilltop settlement of Ultrera is a cold-cut rim in olive green glass (7003-9). A dating suggested by the typology, from the end of the fourth to the early six century CE, corresponds to the dating usually attributed to this Egyptian primary production. Such a correlation is also illustrated by the archaeological glass from *Portus Ilicitanus* (Alicante, Spain; De Juan Ares et al., 2019b, Fig. 1) and by group Foy 1 (Foy et al., 2003, Fig. 3).

4.2.2. The wine glasses

The wine glasses with a hollow stem and a folded foot (type Isings

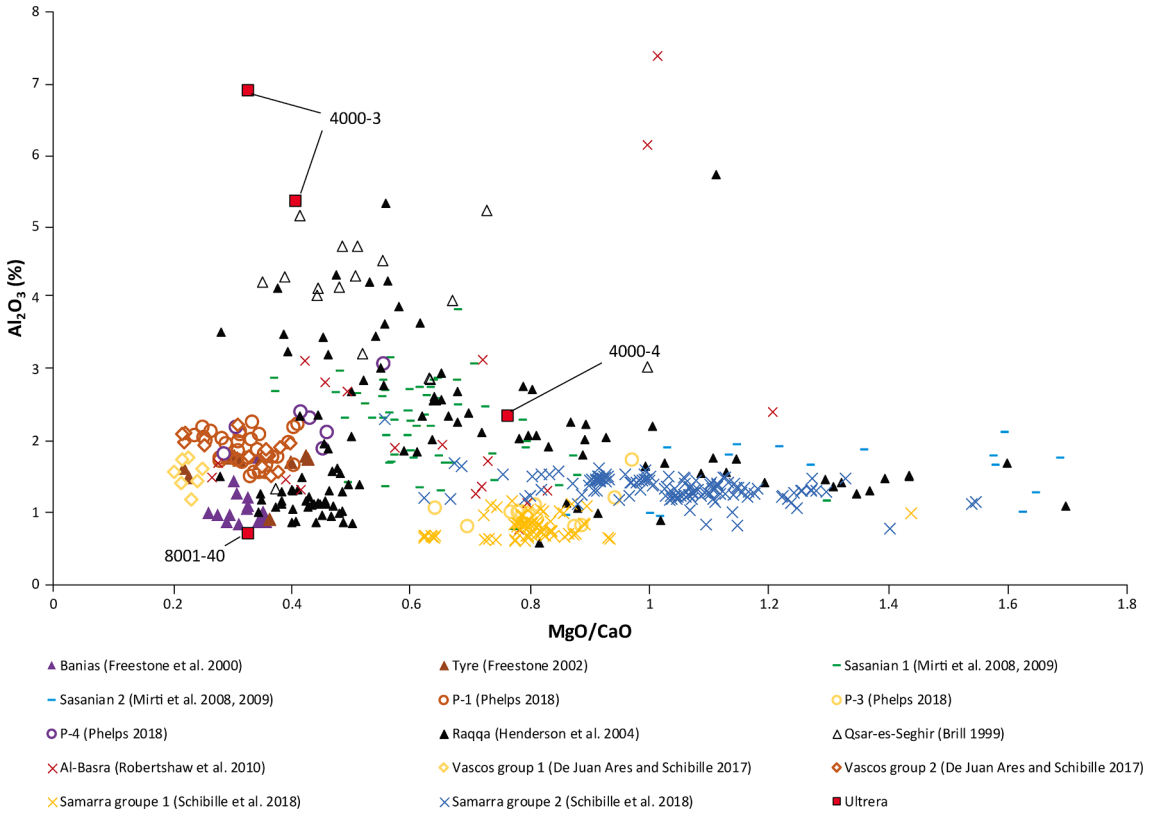

Fig. 8. Samples 4000-3, 4000-4 and 8001-40 compared to Islamic plant ash glass groups from the eastern Mediterranean.

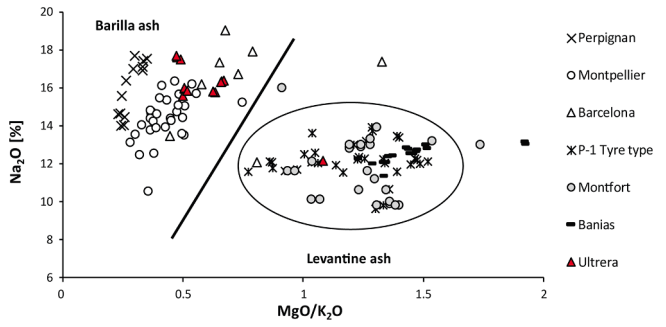

Fig. 9. Soda (Na_2O) versus the ratios of MgO/K_2O of the late medieval plant ash glass from Ultrera and comparative material from Perpignan (13^{th}-14^{th} century CE), Montpellier (13^{th}-14^{th} century CE; unpublished data, IRAMAT CEB), Barcelona (13^{th}-14^{th} century CE; Gimeno et al., 2008), P-1 Tyre type (8^{th}-12^{th} century CE; Phelps, 2018), Banias (11^{th}-13^{th} century; Freestone et al., 2000) and Montfort (13^{th} century CE; Brill, 1999).

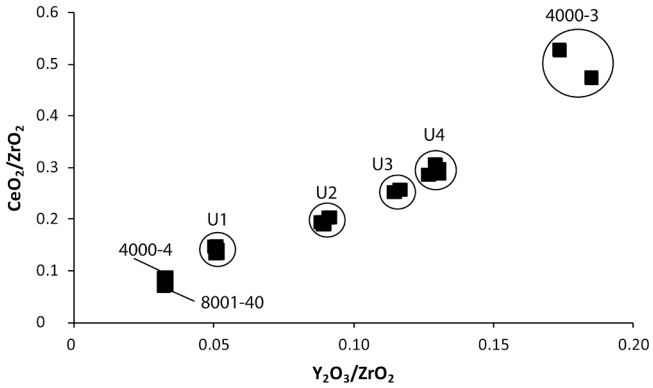

Fig. 10. Distinction of the plant ash objects as a function of yttrium to zirconium and cerium to zirconium ratios: U1 = 8001-43/8002-44/8003-45; U2 = 8007-49/6030-28/6035-30; U3 = 8013-51/8022-52; U4 = 8002-41/8003-46/8004-48/8013-50.

111, Isings, 1957, 139-140) appear in the western Mediterranean at the end of the fifth century CE and are widely used until the first decades of the eighth century CE in southern France (type 23a, Foy, 1995) and in Rome (Arena, 2012, 308-309; Saguì, 1993). The Visigothic sites of Can Gambús and Vilaclara de Castellfollit del Boix also yielded several specimens (Coll Riera, 2011). Two hollow stems from Ultrera (7004-10 and 6034-29) belong to the Foy 2.1 high Fe sub-group, and one sample (6044-32) was probably made from a mix of Levantine 1 raw glass and cullet. Interestingly, ten of the hollow stemmed glasses published by Foy and colleagues (2003) likewise correspond to group 2.1. Three Levantine 1, one Magby and one recycled Levantine example come from the rural Iberian site of Gózquez, which according to their context are dated from the first half of the sixth to the mid-eight century CE (De Juan Ares et al., 2019a). Among the numerous finds of hollow stemmed wine glasses in Italy, the specimens from Aquileia belong to HIMT, Foy 3.2 and Levantine 1 (Gallo et al., 2014), while three examples from Classe correspond to Foy 3.2 (Maltoni et al., 2015). Three Isings 111 goblets from the Gothic fortification of Monte Barro are dated to the late fifth to early sixth century CE and may be identified as Foy 2.1 glasses. The wine glasses from the mid-seventh-century tower of Monselice Rocca include one Foy 2.1, two Foy 2.2 and four Levantine 1 specimens (Salviulo et al., 2004). Of the twenty-four feet of chalices from the *Crypta Balbi* that have been analysed, fourteen date to the seventh century (Mirti et al., 2000, CB1 to CB14) and ten to the eighth century CE (Mirti et al., 2001, CB41 to CB51). The older ones made from Foy 2.1, Foy 3.2 and Levantine 1 glass. The same primary production groups are represented in the eighth-century assemblage, but with a larger proportion of recycled material (group Foy 2.2). Given the long lifespan of hollow stemmed

glasses and their wide distribution throughout the Mediterranean basin, diverse elementary compositions were expected and testify to multiple production centres staggered over time. These vessel types were, for instance, produced in the secondary glass workshop of the island of Maguelone (France), dated to the end of the sixth century CE, using Foy 2.1 raw glass (Foy and Vallauri, 1985; Foy et al., 2003, 56).

The solid stemmed glasses are typical goblets of the late Visigothic period, from the second half of the seventh to the eighth century CE. They may still have been in use at the beginning of the ninth century, even though they were no longer produced under Islamic rule. These wine glasses have thus far only been found in the Iberian Peninsula (Coll Riera, 2011; Gamo Parras, 2010) and in the ancient *Septimania* (Foy, 1995), from the Pyrenees to the Rhone delta. Close to Ultrera, more than twenty solid stemmed glasses have been discovered on the *oppidum* of Ruscino (Foy, 1995). In Catalonia, several solid stemmed glasses come from the fortified hilltop settlement of Puig Rom, above the bay of Roses (Nolla, 1998). This glass shape is indeed quite common, both in rural as well as urban settlements of the late Visigothic period (Coll Riera, 2011; Enrich et al., 1994; Roig Buxó, 2012). Four specimens of Ultrera (1049-17, 6000-19, 6077-37 and 6080-42) are of the Foy 2.2 composition, whereas 6080-39 is an Apollonia-type Levantine 1 glass. From the rural Visigothic sites of Gózquez and El Pelícano come two Levantine 1, one Foy 2.1, one Foy 2.2 and two recycled solid stemmed goblets, dated to between 680 and 750 CE (De Juan Ares et al., 2019a). Only the late use of the group Foy 2.1 is somewhat surprising, while the rest of the results corresponds to the last natron glass typically encountered in western Europe.

4.2.3. *Tubular base of a lamp or a funnel beaker*

The tubular base 1001-15 of light blue glass (phase 3c) could have belonged to a funnel beaker or a lamp with a hemispheric or truncated cone body. They are known throughout the Middle Ages, but the example from Ultrera is closer to seventh- to ninth- century models. In fact, it is similar to several lamps found in the *Crypta Balbi*, dated to the seventh century CE (Arena, 2012, 316-317) or to a Carolingian conical lamp from the abbey of Farfa (Newby, 1991, Fig. 3b). In France, a complete tubular lamp was discovered in the Carolingian village of Villiers-le-Sec (Cuisenier and Guadagnin, 1988, cat. 268). Like the Ultrera sample 1001-15, the chemical composition of the example from the rural church of Evans, in Eastern France, shows clear signs of recycling (Pactat, 2019). The identification of the hollow tubular base as a funnel beaker implies a dating to the late eighth to tenth century, although a date in the ninth century is more likely. Funnel beakers are characteristic of the Carolingian period and they are fairly widespread in Western and Northern Europe (Aunay et al., 2020; Baumgartner and Krueger, 1988; Evison, 2000). Their chemical composition is very variable, including the use of wood-ash glass (Aunay et al., 2020) or mixed-alkali glass (Pactat et al., 2017, Fig. 5A), as well as recycled natron glass (Hunter and Heyworth, 1998). Several funnel beakers with hollow stems belonging to the group Foy 2.2 have been found in the ninth- to tenth-century rural settlements of Maugio, near Montpellier, and Arles/Augéry in Southern France (unpublished data).

4.2.4. *Vessel glass with honey-comb pattern*

Several fragments of the body and base of a bottle (6035-28 and 6035-30), decorated with a mould-blown honeycomb pattern, were discovered in the upper archaeological levels, related to the last frequentation of the site and probably to the occupation of the feudal castle of Ultrera. The chemical composition of these soda plant ash glasses indicates a western production, using *Barilla* ash. This is consistent with the typological attribution of these sherds to facet-moulded bottles with one or more rings around the neck and patterns associating rosettes and hexagonal cells on the body and the shoulder. Native to the eastern Islamic world (Carboni and Whitehouse, 2001, 85; Pollak, 2003), this type of decoration was apparently quickly adopted in al-Andalus (Rontomé Notario and Pastor Rey de Viñas, 2006, 57–58) and remained in use until at least the fourteenth century CE (Capellà Galmés, 2002, 36-37, Fig. 10; Jiménez Castillo, 2000). On the other side of the border, some examples from twelfth- to thirteenth-century contexts have been discovered at Vilarnau, close to Perpignan (Mach, 2008). These bottles, blown in a relatively thick blue-green glass, became one of the most widespread containers in Provence and the Mediterranean Languedoc from the late thirteenth to the fifteenth century CE (Foy, 1988, 241-250; Foy and Michel, 2014, 273-276; Mach, 2014).

4.2.5. *The beads*

The yellow-green melon bead 6028-25 has been classified as Foy 2.1 high Fe, which seems to appear in Visigothic Spain sometime in the first half of the sixth century CE alongside Foy 2.1 (De Juan Ares et al., 2019a). It was discovered in a seventh- to eighth-century context, but the typology of this bead, characterized by more than ten ribs and its colour, makes it possible to reduce the dating to the period between 520/530 and 630/640 (Pion, 2014).

The beads 4000-3 and 4000-4 come from the same context and are both made from soda plant ash glass, but probably originated from different production regions, according to the flux and some elements related to the silica source (see 4.1.2 and Fig. 9). The only possible parallel we have found for the black and white bead (4000-3) stems from al-Basra (Morocco) that was recovered from a deposit dating back to the reconstruction of the city during the Almoravid period (Robertshaw et al., 2010). It was also produced in a soda plant ash glass with a similarly high alumina content. The cobalt blue bead 4000-4 is typologically similar to an example from the Castle of Prague (Černá et al., 2005, n°26) that was unfortunately not analysed. However, some of the associated material turned out to be plant ash and lead-rich beads, dated from the ninth to the eleventh century CE. As for the composition, several cobalt blue beads from Komani and Lezha (Albania) are made from the same Mesopotamian soda plant ash glass, coloured by a zinc-rich cobalt colorant (Neri et al.,2017).

4.2.6. *The linen smoother*

The linen smoother 6054-34 is shaped in a dark glass with olive green inclusions, but its surface is now totally corroded. Linen smoothers are typical glass artefacts of the Carolingian period that have been recovered from numerous ninth- to eleventh-century contexts across western and northern Europe, but they are less frequent in southern France (Foy, 2001, note 17; Foy, 2015, 63), sporadically reported in northern Italy (Maurina and Pezzato, 2016, 480-482; Nepoti, 2014) and practically absent from the Iberian Peninsula (Gratuze et al., 2014). The majority of the smoothers were made from wood ash glass, a substantial number corresponds to a unique type of silica-lime-alumina-lead glass from the mining activities in Melle, France (Gratuze et al., 2014), while only a few natron glass samples are known (Uboldi and Verità, 2003). The Ultrera specimen is of the wood ash category, a composition that emerged in continental Europe in the second half of the eighth century CE, but it is unusual in southern Europe and around the Mediterranean. Two linen smoothers from the *Grotte des Églises* (Ariège, France) and from the *Cova de les Encantades de Martís* (Girona, Spain) are wood ash glass, too (Clop et al., 1998). The northern Italian smoothers – or *pani di vetro* – from Sant'Andrea di Loppio (Silvestri et al., 2016) and Sant'Agata Bolognese (Nepoti, 2014) belong to the same compositional group. The most common interpretation of these glass discs is related to textile or leather working activities, such as smoothing and polishing (Ferdière, 1984, 227-228; Watson et al., 2011, 45), but they may have also assumed more symbolic or apotropaic significance (Foy, 2004). The discovery of empty specimens, probably blown (Nepoti, 2014; Steppuhn 1999), and the lack of correlation with a glass-working activity in most of the sites refute an interpretation as glass ingots.

4.3. Glass consumption profile of Ultrera and the evolution of glass recipes

4.3.1. Fifth to eighth centuries CE

The cold-cut rim 7003-9, belonging to the HIMT group, was discovered in a seventh- to eighth-century context and might represent residual material from the first medieval occupation phase (phase 2a), unless the beaker has been used for several decades.

Most of the vitreous material is dated to the seventh to eighth centuries CE and comes from zone 6, which is an important building on stone foundations for domestic and artisan use. Four samples were found in zone 1, while less than ten specimens come from the North District. The repertoire consists mainly of drinking goblets, with or without stem. The glass of phase 2b belongs to Foy 2.1, Foy 2.1 high Fe, Foy 2.2, Foy 3.2, Levantine 1 and recycled Levantine 1. The stratigraphy does not allow a more precise chronological analysis of the development of the glass recipes but, according to the typological observations, the Foy 2.2 sub-group is probably somewhat later than the others.

The seventh- to eighth-century glass material from Ultrera is quite significant and comparable with the numerous finds from the *castrum* of Puig Rom, above the bay of Roses (Nolla, 1998) or with those from the *oppidum* of Ruscino, near Perpignan (Foy, 2015). During this period, glass appears to be ubiquitous and not just a commodity reserved for an elite. The glass assemblage from Visigothic rural sites confirm this assessment (De Juan Ares et al., 2019a; Gamo Parras, 2010). It can be speculated that some of it was imported from the Byzantine Empire or from the Frankish Kingdom, but the existence of typical Visigothic forms implies that several secondary glass workshops were established in the region. They could easily be supplied via the harbors of Port-Vendres (Foy, 2016), Collioure or Roses, and there was no lack of demand.

4.3.2. Late eighth to tenth centuries CE

Eleven natron glasses were found in levels of phase 3. The two Roman glasses (6001-20 and 6035-31) were probably introduced from another ancient site. Only the hollow stemmed goblet 6034-29 and the rounded rim 4000-5, belonging to Foy 2.1 high Fe and Levantine 1, respectively, are free of signs of recycling. Five specimens, including the solid stemmed glass 1049-17, are Foy 2.2 glasses. The hollow stemmed vessel 6044-32 was produced using predominantly Levantine 1 glass, while the tubular bottom 1001-15 is the result of recycled Roman glass. Recycling was already noticed during the previous phase, but it seems to increase in phase 3. Hollow and solid stemmed goblets are also forms found in phase 2b and they may be residual. However, the stratigraphy and the study of other materials, like ceramic, have demonstrated that this phenomenon is very limited. Thus, we can postulate that some late Visigothic products were still in use during phase 3.

Only the two beads found in the North District are evidence of Islamic imports: the cobalt blue one (4000-4) is undoubtedly from Mesopotamia, while the origin of the black and white bead (4000-3) is not clear. They were discovered in the last occupation phase (late eighth to tenth century CE). Apart from the two beads, Islamic glass is conspicuous by its absence, despite the relative proximity of Muslim lands and despite the fact that several Islamic glass artefacts have been found in Christian contexts, especially in religious and funerary environments, often in the form of small glass flasks (e.g. Foy, 1997; Velasco and Whitehouse, 2012; Velasco et al., 2011; Vellido and Guardia, 2014). Nonetheless, the two beads indicate some contact between Ultrera and al-Andalus. Glass finds are generally absent from the Carolingian occupation, only the linen smoother represents a typically Carolingian commodity. Glass tableware seems to have completely disappeared and consumer habits have undoubtedly changed. In this respect, the glass consumption profile in the south of France contrasts with that in the north of the country (Aunay et al., 2020; Motteau, 1985; Mouny, 2008). For instance, the extensive excavations of the lowland site of Taxo-Les Gavarettes, occupied without interruption from the second half of the sixth to the twelfth century CE, have mainly yielded Visigothic vessel glass. Only one specimen of a folded foot made of wood-ash glass was discovered (unpublished data). Specific productions are occasionally discovered on elite sites of the tenth to eleventh centuries CE, such as the castle of Fenouillet (Foy et al., 2017, 161) or that of Termes (Cazes, 2014, 147). Unlike in earlier centuries, vitreous material must clearly be considered a luxury good at this time and in this region.

4.3.3. Thirteenth to fifteenth centuries CE

The soda plant ash glass vessels are concentrated in zone 8, with the exception of two samples in zone 6 that is 5–10 m apart. They are consistent with late medieval productions (thirteenth to fifteenth century) from the local region such as Montpellier, Perpignan or Barcelona. Only the cobalt blue glass 8001-40 may be a slightly older imported object, as it is made with Levantine ash and resembles the glass from Banias (eleventh to thirteenth century) and Montfort (thirteenth century) in Israel. This assemblage is not linked to the early medieval settlement, but most probably to the occupation of the castle of Ultrera (eleventh to seventeenth centuries CE), built close to the top of the mountain range. These glasses were found at the top of levels associated with phase 3c which were contaminated by the frequentation of zones 6 and 8 after the abandonment and the destruction of the site. The main access to the feudal castle passed through this area.

5. Conclusion

Far from being an isolated refuge or garrison, our study of the archaeo-vitreous material suggests that Ultrera/Ultrère cultivated close relations with the coastal region even before the establishment of the feudal castle in the second half of the tenth century CE (Constant et al., 2018). Although the *castrum* is located in a mountainous area, it was evidently firmly integrated into the Mediterranean trade networks and its proximity to the coast and major trade routes favoured a regular supply of various goods, including vitreous materials of Egyptian and Levantine provenance. The increase in recycling at the end of the period probably points to a shortage of imports and some disturbances in the long-distance trade. However, the continued existence of pristine Levantine 1 glass shows that connections with the Eastern Mediterranean were still in place.

In the ninth and tenth centuries, the settlement depicts a different situation. The *castrum* becomes a strategic place of the Frankish and Christian Reconquista of Muslim territories (Constant, 2007; Constant, 2020). Glass from this period is practically non-existent in the archaeological record, with the exception of a linen smoother, two Islamic beads and a tubular bottom of a funnel beaker or a lamp. Some products of the previous phase may still have been used, but in a limited way. This seems to be a general trend at regional level, but it could also indicate that the status and the nature of the occupation have changed. From the end of the ninth century CE, the progressive independence of the Catalan counties could explain the near absence of typical Carolingian glass forms, like funnel beakers, globular pots or footed beakers (Aunay et al., 2020). This period also sees a change in the glass production system with the advent of the first Western European workshops producing glass from wood ash (Pactat et al., 2017; Wedepohl et al., 1997). There is no evidence of any glass workshop from this period in the region, the closest one is near Toulouse (unpublished data). Even if the glass industry in southern France seems to have experienced a temporary decline, some productions may be local, such as tronconic goblets with blue or green bands (Foy, 2015). None of them seem to have reached the Pyrenean massif, despite the fact that the site appears to have been remarkably prosperous, judging from the massive constructions, and the remains of fauna and ceramics. In contemporary Catalan sites, especially monastic ones, Islamic objects are among the rare finds, often chosen for their decoration and reused as *lipsanoteca*. The absence of glass in the ninth and tenth centuries can therefore be explained both by the development of a new production system and by consumption practices directly influenced by the geopolitical context of the region. The remains

from the thirteenth and fourteenth century, probably from the feudal castle of Ultrera, show that these customs changed again at the end of the Middle Ages.

CRediT authorship contribution statement

Inès Pactat: Conceptualization, Data curation, Investigation, Visualization, Writing – original draft, Writing – review & editing. **André Constant:** Resources, Investigation, Writing – review & editing. **Nadine Schibille:** Conceptualization, Data curation, Investigation, Funding acquisition, Resources, Supervision, Writing – original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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