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Transformations of the Mediterranean glass supply in medieval Mazara del Vallo (Sicily)

Nadine Schibille, Francesca Colangeli

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Mazara/Māzar: nel ventre della città medievale (secoli VII-XV)

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III.2 TRANSFORMATIONS OF THE MEDITERRANEAN GLASS SUPPLY IN MEDIEVAL MAZARA DEL VALLO (SICILY)

INTRODUCTION

An increasingly complex picture of the transformation of the Mediterranean glass industry in the latter part of the first millennium CE emerges from an expanding archaeological record and the multiplication of analytical studies of glass assemblages. Prior to the eighth century, the primary glassmaking industries on the Levantine coast and in Egypt supplied the glass market of the entire Mediterranean with soda-lime-silica raw glass produced from a mixture of mineral soda from Egypt (so-called natron) and quartz-rich sand as the source of silica (DEGRYSE 2014; FREESTONE 2005, 2006; FREESTONE *et al.* 2018; FREESTONE *et al.* 2000). The production capacities of Roman and late antique primary production centres in the Levant and Egypt were enormous, giving rise to relatively homogeneous compositional groups that allow glass from consumer sites to be traced back to their place of origin in the eastern Mediterranean (FREESTONE *et al.* 2000; FREESTONE *et al.* 2008; TAL *et al.* 2004; GORIN-ROSEN 1995; GORIN-ROSEN 2000; NENNA *et al.* 2000; THIRION-MERLE *et al.* 2003; NENNA *et al.* 2005; NENNA 2015; JACKSON *et al.* 2018). A shift in the distribution pattern of natron glass can be observed in the western Mediterranean in the second half of the sixth century, when the previously dominant Egyptian glass groups (Roman Sb, HIMT, Foy 2.1) are gradually supplanted by the Levantine I compositional group that matches the remains of the primary glassmaking furnaces excavated at Apollonia (Arsuf, Israel) (FREESTONE *et al.* 2008; BREMS *et al.* 2018). Declining imports of fresh glass in the seventh and eighth centuries led to an intensification of recycling practices and ultimately to the development of new local glassmaking traditions in the western Mediterranean.

The rate of this transformation and the adopted strategies differ from region to region. In the Iberian Peninsula, for example, new glassmaking recipes were developed in the second half of the eighth or first quarter of the ninth century CE with lead oxide as the main ingredient (SCHIBILLE *et al.* 2020), followed by a soda ash lead glass in the ninth and soda ash silica glass possibly in the tenth century (CARMONA *et al.* 2009; DUCKWORTH *et al.* 2015; DE JUAN ARES, SCHIBILLE 2017; DE JUAN ARES *et al.* 2021). In Carolingian Europe the use of potash rich wood ash instead of mineral natron or soda-rich plant ash as the main fluxing agent was introduced as early as at the end of the eighth century (VAN WERSCH *et al.* 2016; VELDE 2009; WEDEPOHL, SIMON 2010). The use of wood ash was firmly established by the tenth century throughout central Europe (WEDEPOHL, SIMON 2010; WEDEPOHL *et al.* 2011). Surprisingly little is known about the evolution of glass compositions in Italy in the last quarter of the first millennium CE. The earliest soda ash glass found in Italy date to the ninth century, but they most certainly represent imports from the Islamic east (CAGNO *et al.* 2012b; NERI *et al.* 2019; SILVESTRI *et al.* 2005; VERITÀ 2013). While there is some

evidence of regional variations in the compositional make-up of medieval Italian glass assemblages between the north and the south of the peninsula, glass recycling appears to have been widespread until the twelfth century (BERTINI *et al.* 2020; NERI *et al.* 2019; VERITÀ 2013). In the twelfth or thirteenth century, Venice began the primary production of glass using soda-rich plant ash imported from the Levant (VERITÀ *et al.* 2002).

To date, glass assemblages from early medieval Sicily remain largely unexplored. Mosaic tesserae dating to the late Roman period from the Villa del Casale near Piazza Armerina have been analysed and are all of the natron type (CROVERI *et al.* 2010; DI BELLA *et al.* 2014; VERITÀ 2017). Similarly, Roman glass compositions were identified among the glass finds from the church of St. Agata la Vetere in Catania, broadly dated to the second to eighth century CE (BARBERA *et al.* 2012), while some fourth- to seventh-century glass fragments from Ganzirri north of Messina are a mixture of different late antique natron glass groups (ARLETTI *et al.* 2010). The majority of samples recovered from the late antique secondary glass workshop in the amphitheatre of Catania belongs to the high iron, manganese and titanium (HIMT) compositional group (DI BELLA *et al.* 2015). A study examining the compositional features of a fourteenth-century glass assemblage from Poggio Diana Castle near Agrigento is thus far the only one to investigate soda-rich plant ash glasses from Sicily (PANIGHELLO *et al.* 2013). Even though none of these published datasets coincides chronologically with the glass finds from Mazara, they provide contextual information and help tracing temporal developments.

The investigation of the vitreous material from Mazara del Vallo that spans the seventh to the thirteenth century represents the first comprehensive analytical study of Sicilian glass at a time when the production and trade of glass in the Mediterranean underwent fundamental changes. The importance of Sicily as a whole and of Mazara del Vallo located on the west coast of the island is its strategic position connecting the western and eastern Mediterranean. In the tenth and eleventh century, Mazara was an important commercial hub and integrated in interregional trade links with Tunisia and Egypt, featuring repeatedly in the Cairo Geniza (*infra* MOLINARI). Although the absolute number of glass finds is comparatively limited (a total of 79 objects), the analysis of the majority of these samples (n = 50) allowed us to assess the variability of the chemical composition of the assemblage within three distinct periods: a Byzantine phase in the seventh to eighth centuries, followed by tenth- to eleventh-century Islamic Sicily and the thirteenth-century Swabian occupation. The chronology of the finds was determined on the basis of associated ceramic finds, coins, some ¹⁴C data and stratigraphic relations (*supra* MEO, cap. I.2). The glass finds from Mazara are thus ideally suited to explore the transformational mechanisms underlying the Mediterranean glass industry as a function of wider socio-economic developments.

This paper evaluates the analytical data of the Mazara glass finds in light of recent advances in the classification of soda ash glasses from the Near East and the Mediterranean region in the late first and early second millennium CE. The overall objective is to investigate the possible beginnings of a Sicilian glassmaking industry and to evaluate the role of geopolitical changes in the production and consumption of glass in Sicily. It has long been assumed that soda-rich plant ash glassmaking did not commence in Italy before the twelfth century in Venice (VERITÀ 2013). As will become clear in the following, the distinct compositional features of the glass from Mazara suggest an alternative scenario for Sicily. Here, soda ash glasses prevail from the tenth century on and at least some, if not all may be the output of a Sicilian primary glassmaking industry.

1. MATERIALS AND METHODS

Fragments of 50 individual glass objects including 3 dual colour samples were selected for laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Small samples from each fragment were embedded in epoxy resin and polished to remove any residues and surface alterations. For the analyses, a Thermo Fisher ELEMENT XR mass spectrometer was used together with a Resonetics M50E excimer laser operating at 193 nm at 5 mJ and a frequency of 10 Hz. The analyses were carried out in the spot mode with a beam diameter of 100 μm for glass with low manganese concentrations ($\text{MnO} < 0.5\%$). For samples with higher manganese and/or elevated copper oxide contents, the diameter was reduced to 80 μm and occasionally to 60 μm to avoid saturation. Following a pre-ablation time of 20 s to eliminate the transient part of the signal, the average counts per second of 58 elements were acquired during 30 s. To calibrate the system and to allow for a full quantification of the results, blanks as well as five different standard reference materials were run every 10 to 13 samples. The standards (NIST 610, Corning B, C and D, and APL1, an in-house standard for the quantification of chlorine) are used to determine the average response coefficient (K_c) for each element, while ^{28}Si is used as an internal standard for normalisation to obtain fully quantitative data. The analytical protocol and calculation procedures have been described before (GRATUZE 2014, 2016). To monitor the analytical precision and accuracy of the results, Corning reference standards A, B, C and D and NIST 612 were systematically analysed throughout the sequence. Both, precision and accuracy are generally within 5% to 10% of the published values, depending on the absolute abundance of the element.

2. RESULTS

The full compositional data of the Mazara glass assemblage are given in *tab. 1*. All the glass finds are consistent with the category of soda-lime-silica glass that can be separated on the basis of the alkali sources into natron and plant ash glass types (*fig. 1a*). The samples dating to the seventh and eighth centuries correspond exclusively to natron type glass produced from a mineral soda with low potash, magnesia (both $< 0.6\%$) and phosphorus contents ($\text{P}_2\text{O}_5 < 0.2\%$). Both later groups are high-magnesia and high-potash glasses with elevated phosphate, produced from a soda-rich plant ash as the principal fluxing agent. The lime and soda concentrations do not differ significantly between the natron and plant ash glass groups (*fig. 1b*). Hence, the glass assemblage from Mazara as a whole reflects the transformation in glassmaking recipes at the end of the first millennium CE. While the earlier glasses adhere to the Roman

and late antique glassmaking technology, utilising mineral soda as flux, the tenth- and eleventh-century finds represent relatively early examples of plant ash glass in the western Mediterranean.

SEVENTH- TO EIGHTH-CENTURY NATRON GLASS

The natron type glass from Mazara is characterised by moderate soda ($\text{Na}_2\text{O} \sim 14.7\%$) and lime concentrations ($\text{CaO} \sim 8.9\%$), and fairly high alumina contents ($\text{Al}_2\text{O}_3 \sim 3.2\%$) (*tab. 1*). All other elements related to the silica source such as titanium ($\text{TiO}_2 \sim 0.07\%$), iron ($\text{Fe}_2\text{O}_3 \sim 0.41\%$) and zirconium ($\text{Zr} \sim 37$ ppm) remain very low, while manganese is consistently at levels that can be attributed to the natural impurities of the sand raw material ($\text{Mn} < 200$ ppm). These features are compatible with glass produced on the Levantine coast, and more precisely with the compositional group originally called Levantine I. This group was defined on the basis of the glass remains from the primary glassmaking installations at Apollonia (Arsuf, Israel) dating to the sixth and seventh century CE (FREESTONE *et al.* 2000; FREESTONE *et al.* 2008; BREMS *et al.* 2018). The affiliation with Levantine glass becomes clear when comparing the Mazara samples to different known seventh- to eighth century production groups from the Levantine coast and Egypt (*fig. 2a*). Levantine glass tends to have considerably lower titanium to aluminium oxide ratios compared to Egypt 1 (eighth century) and Egypt 2 (eighth to ninth century) while the alumina to silica ratios occupy an intermediate range.

Classifying the various Levantine glass categories is more complex. Broadly speaking, four chronologically different Levantine glass groups can be distinguished: Roman manganese and naturally blue-green coloured glass, glass from the fourth-century workshop at Jalame, Apollonia type Levantine I glass dating to the sixth and seventh centuries, and finally Bet Eli'ezer type Levantine II, probably of an eighth-century date (FREESTONE *et al.* 2000; PHELPS *et al.* 2016; BREMS *et al.* 2018). The Roman and Jalame groups can be excluded on chronological as well as compositional grounds, as they tend to have higher soda and lower lime and alumina levels (PHELPS *et al.* 2016). Apollonia type Levantine I differs from Bet Eli'ezer type Levantine II in terms of the carbonate and feldspar fractions of the sand source as well as the soda to silica ratios (*fig. 2b*). Bet Eli'ezer Levantine II glass has the lowest soda levels of all the natron type glasses, indicating differences in the recipes and the relative proportions of fluxing agent to silica source (FREESTONE *et al.* 2000). The lime to alumina and soda to silica ratios of the seventh- to eighth-century fragments from Mazara clearly correspond more closely to Apollonia Levantine I than to Bet Eli'ezer Levantine II glass (*fig. 2b*). Moreover, the sum of the elements typically associated with the colouration and/or opacification of glass that can serve as markers of recycling in colourless glass remains well below 100 ppm (*fig. 2c*). This means that the seventh- and eighth-century glass from Mazara represents essentially pristine Apollonia type Levantine I glass and may have been imported either as raw glass chunks and worked locally or imported in the form of finished objects.

From a typological point of view, all the seventh and eighth-century objects are small goblets classified as Isings 111 (*fig. 4; supra* COLANGELI). These types of goblets are relatively common and widespread throughout Italy and the Mediterranean. Examples are known from the Levantine coast, Egypt, Tunisia and the south of France, dating to the second half of the sixth century (FOY *et al.* 2003; WINTER 2019). In Italy, where a drastic decline in typologies has been observed in parallel with a general decrease in the amount of vitreous material from the sixth century onwards, these goblet types are among the few that

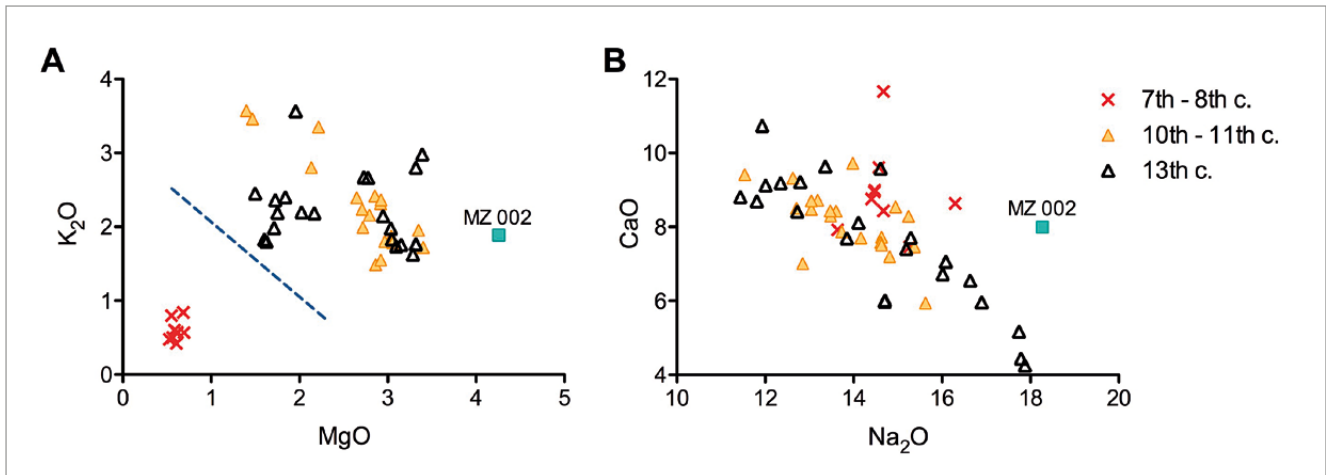


fig. 1 – Separation of the Mazara assemblage into chronologically distinct groups. (a) Potash versus magnesia levels separate the seventh- and eighth-century mineral soda glass from the later soda-rich plant ash glass; (b) lime and soda concentrations are relatively constant across the majority of samples.

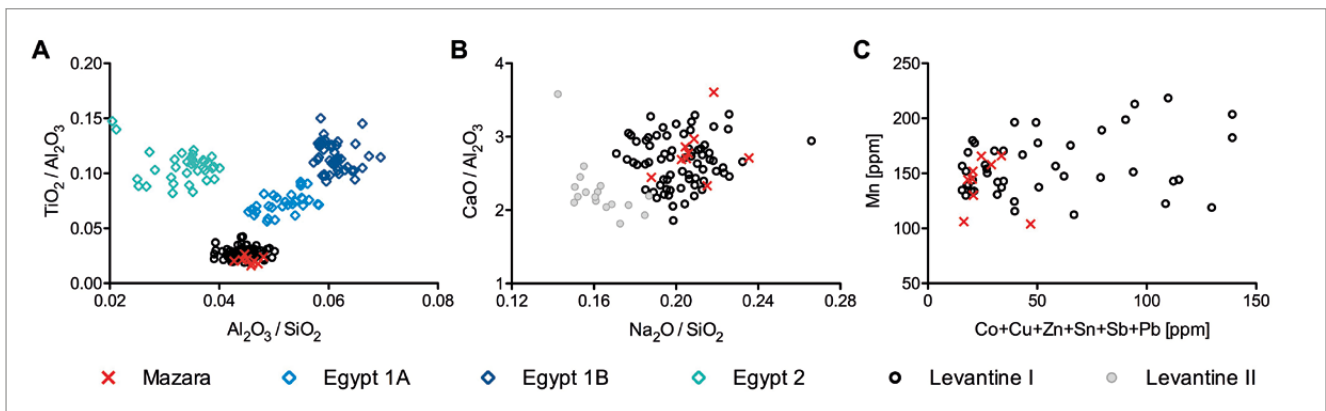


fig. 2 – Compositional characteristics of the natron type glass from Mazara. (a) TiO₂/Al₂O₃ and Al₂O₃/SiO₂ ratios represent the heavy mineral and feldspar fractions relative to the silica source, and identify the Mazara samples clearly as Levantine glasses; (b) ratios of lime to alumina and soda to silica separate Apollonia type Levantine I glasses from the Bet Eli‘ezer Levantine II group, underscoring the similarities between the Mazara finds and Levantine I; (c) elements associated with colouring and/or opacifying as markers of recycling in colourless glass remain below 100 ppm, implying that the Mazara glasses have not been extensively recycled. Data sources: for Apollonia type Levantine I and Bet Eli‘ezer Levantine II (PHELPS *et al.* 2016; BREMS *et al.* 2018); for Egypt 1A, 1B and 2 (SCHIBILLE *et al.* 2019).

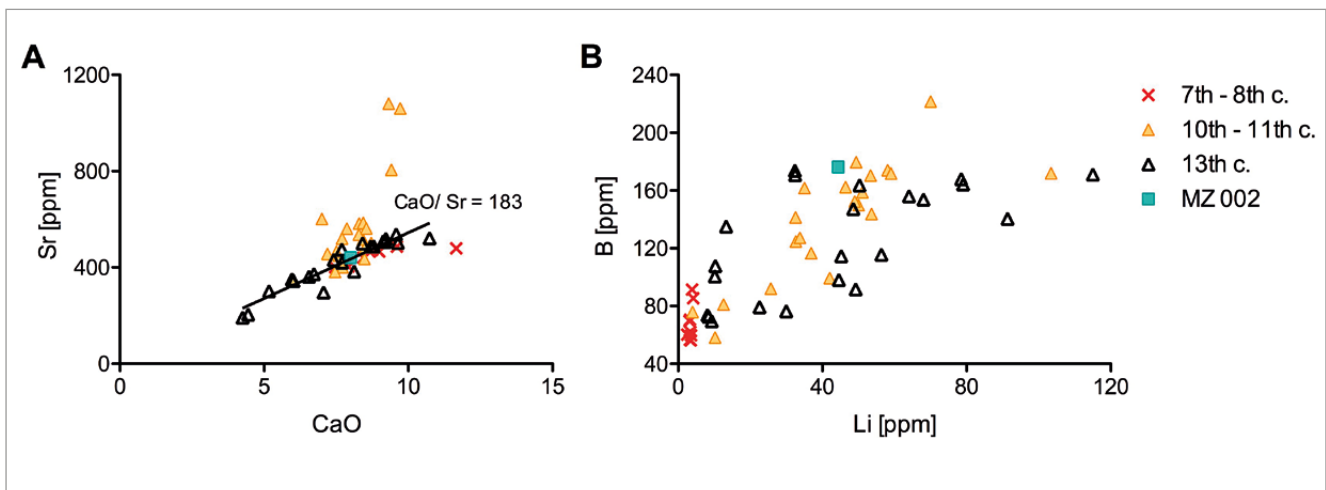


fig. 3 – Chemical properties of the plant ash component of the two chronological groups from Mazara. (a) Strontium and lime ratios are similar for the majority of glass samples, with the exception of some eleventh-century samples with higher concentrations probably caused by fuel ash contaminations. A sub-group dating to the thirteenth century has overall lower alkaline earth metals; (b) lithium and boron concentrations are elevated and positively correlated.



fig. 4 – Goblets (Isings 111) of the seventh- and eighth-century contexts.

survived into the eighth century (SAGUÌ, LEPRI 2016). The same trend is noticeable in Sicily, where small goblets are the only glass objects recovered not only from Mazara del Vallo but also at Mount Kassar (CARVER *et al.* 2019). There is no conclusive archaeological evidence of secondary glass working in Sicily at the time, and given the ubiquity of these goblets, the typology gives no further indication as to where the objects were made or in what shape and form the glass arrived at Mazara.

SODA-RICH PLANT ASH GLASS

Turning to the soda-rich plant ash glass, the samples from the tenth and eleventh centuries and the majority of the finds attributed to the thirteenth century largely overlap with respect to both the plant ash component as well as the silica source. With very few exceptions (e.g. MZ 002), magnesium and potassium oxides range between 1.5% and 3.5% (fig. 1a), which are generally considered to be the result of using ashes of halophytic plants as the primary fluxing agent (FREESTONE 2006; LILYQUIST, BRILL 1993; SAYRE, SMITH 1961). Three of the tenth- and eleventh-century samples have notably higher potash levels (MA 011, 012, 247) relative to magnesia, which may have been caused by contaminations through fuel ash that has also augmented the strontium and lime levels of these samples (fig. 3a). A sub-group of the thirteenth-century fragments have on average lower alkaline earth metals, and include two of the dual colour samples (MZ 263, 269) as well as three of the pruned beakers (MZ 005, 251, 268; tab. 1). The alkali source is furthermore characterised by elevated boron and lithium contents that are positively correlated (fig. 3b). Except for some individual samples, no systematic differences in the plant ash component between the tenth-/eleventh- and the thirteenth-century glass could be identified.

Similarities between the plant ash glasses also extend to elements associated with the silica source. Aluminium, iron and titanium contents vary within relatively narrow limits (fig. 5a, b). In most samples, alumina ranges from about 1.5% to 2.5%, iron oxide from 0.5% to 1.5% and titanium oxide from about 0.11% to 0.18% (average TiO_2 ~ 0.14%). The bulk of the plant ash glass has relatively high heavy element concentrations such as zirconium, hafnium, tantalum and thorium (fig. 5c). Two of the dual colour fragments (MZ 263, 269) have markedly different titanium to zirconium ratios, suggesting the use of different silica sources and thus different origins (fig. 5b). One sample dating to the first half of the eleventh-century (MZ 247), and one thirteenth-century fragment (MZ 002) stand out for their distinctive trace element profiles (fig. 5c). MZ 247 has considerably lower heavy elements relative to the rare earth

elements (REEs), while MZ 002 has the lowest levels across all trace elements and REEs, alongside some of the highest soda and magnesia concentrations (tab. 1).

The most significant compositional difference between the two chronological groups is the amount of manganese oxide. Whereas the thirteenth-century glass contains on average only 0.6% MnO within a relatively narrow range (fig. 6a), the earlier plant ash glass has clearly higher levels of manganese (MnO ~ 2%) that are overall positively correlated with iron oxide, indicative of the use of a manganiferous material for decolouring (or colouring) purposes. The presence of considerable amounts of manganese (MnO > 0.5%) as decolouring agent is known from early Islamic glass assemblages in Mesopotamia, the Levant and Egypt. Its addition is related to the primary production stage as documented by the data from the primary glassmaking furnaces at Tyre (FREESTONE 2002), the workshop at Baniyas (FREESTONE *et al.* 2000), as well as Raqqa (HENDERSON *et al.* 2004). The absence of manganese in most of the thirteenth-century glass finds from Mazara therefore suggests a change in the primary production of these plant ash glasses. An excess of manganese (MnO > 4%) in two samples (MZ 006, 015) archaeologically dated to the thirteenth century is responsible for their deep purple colour (fig. 6a).

Only a handful of glass finds have been intentionally coloured with either manganese, copper or cobalt (tab. 1). Two eleventh-century finds (MZ 009, 260) are copper blue fragments, and three thirteenth-century vessels have cobalt blue decorations (fig. 6b, c). The cobalt colourant is associated with elevated zinc, indium and lead concentrations. The rest of the plant ash glass finds is weakly coloured (greenish or bluish aqua) to colourless. Many of the tenth- to eleventh-century samples still contain considerable levels of colourants (> 100 ppm), reflecting the addition of coloured cullet at some point during the life cycle of these glasses (fig. 6b). Recycling markers are not as pronounced in the thirteenth-century glass, suggesting that either recycling was not as common during the later period or that the incorporation of coloured material was more limited. This is in keeping with our previous observation that primary glassmaking changed sometime between the eleventh and the thirteenth centuries, even though the base glass composition (silica and plant ash constituents) remains largely unchanged.

In parallel, the typology of the objects changes significantly between the eleventh and the thirteenth century, reflecting different cultural forces at work in Mazara. The most representative type of objects in the Islamic period (tenth and eleventh century) are small flasks for pharmaceutical or medical use such

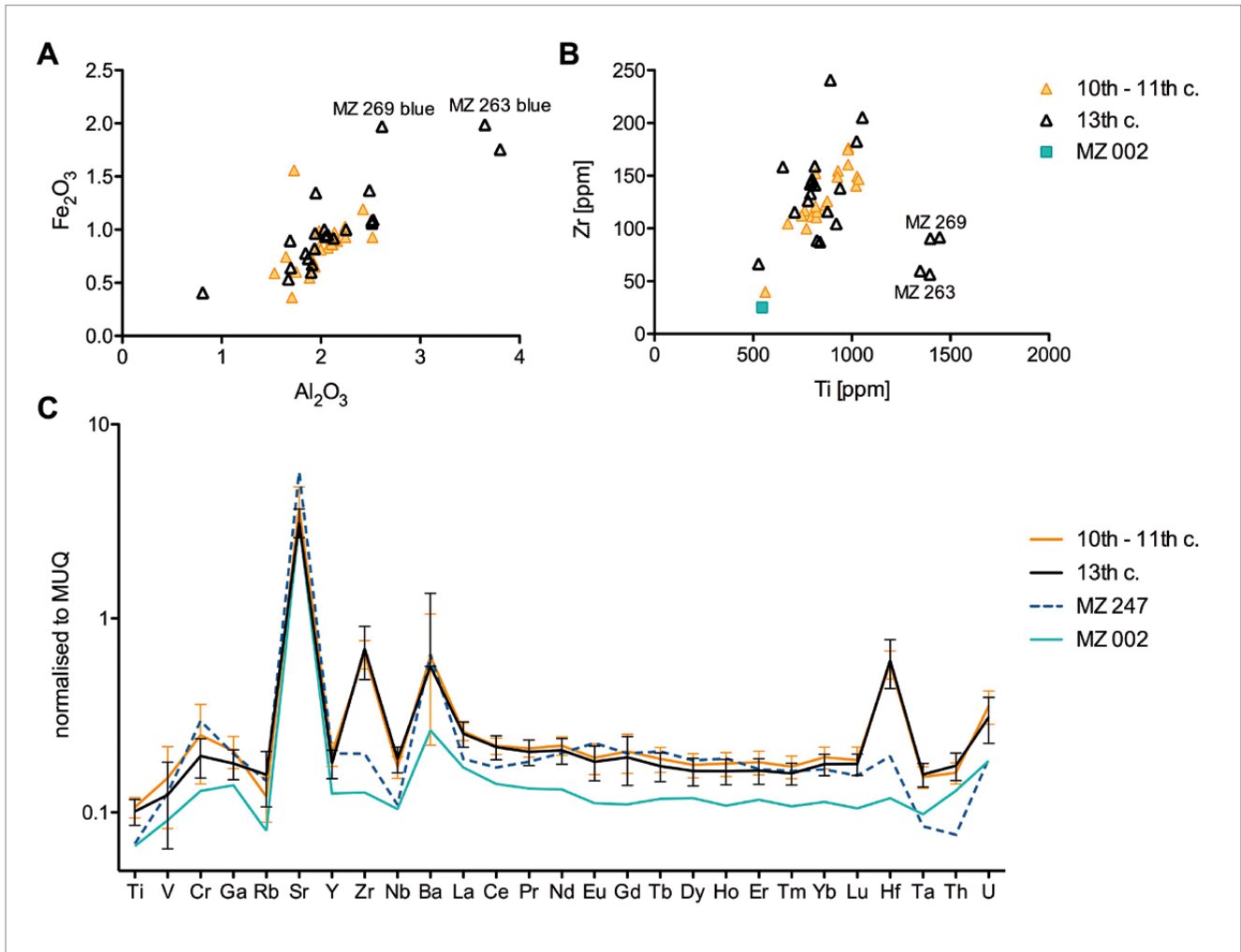


fig. 5 – Elements associated with the silica source of the plant ash glasses from Mazara separated into chronological groups. (a) Aluminium and iron oxides are overall positively correlated with the possible exception of the cobalt blue fragments; (b) titanium and zirconium also show a positive correlation. Two dual colour samples are highlighted (MZ 263, 269, 2 measurements per object); (c) average trace element profile of the two chronological groups and two individual samples (MZ 002 and MZ 247). Note that samples MZ 263, 269 were excluded from the means of the thirteenth-century group; error bars indicate the standard deviation (SD).

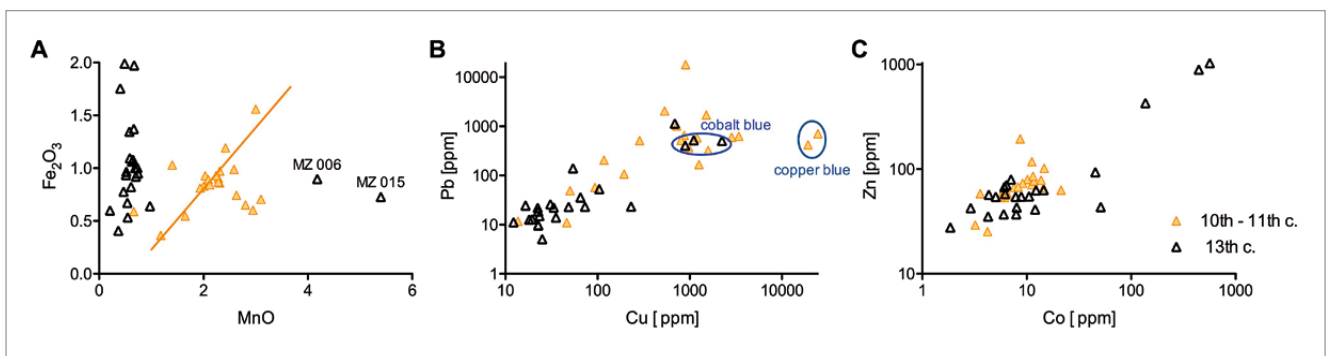


fig. 6 – Colouring and decolouring agents in the plant ash glasses from Mazara. (a) Manganese and iron concentrations separate the tenth- and eleventh-century samples clearly from the thirteenth century group; (b) copper and lead contents are elevated particularly in the tenth- and eleventh-century plant ash group, implying a certain degree of recycling, while they are associated with the colouring process in the cobalt blue samples; (c) the cobalt colourant in three samples is associated with elevated zinc (and indium, *tab.* 1), identifying a European cobalt source.

as small conical bottles with a long tubular neck, square flasks with pinched sides, globular shapes, and what may have been an alembic (fig. 7; *supra* COLANGELI, type VI.1). These typologies are very common both in other Sicilian contexts of the same period (COLANGELI 2021; OTTATI 2012) as well as in the

Maghreb, for example in Šabra al-Manšūriya (Qayrawān) (*supra* COLANGELI) (FOY 2012, 2020; SCALON, PINDER-WILSON 2001). Only about 25% of the Islamic assemblage represent tableware in the form of mould blown bottles and beakers. Interestingly, sample MZ 247 that has a Levantine plant ash glass composition

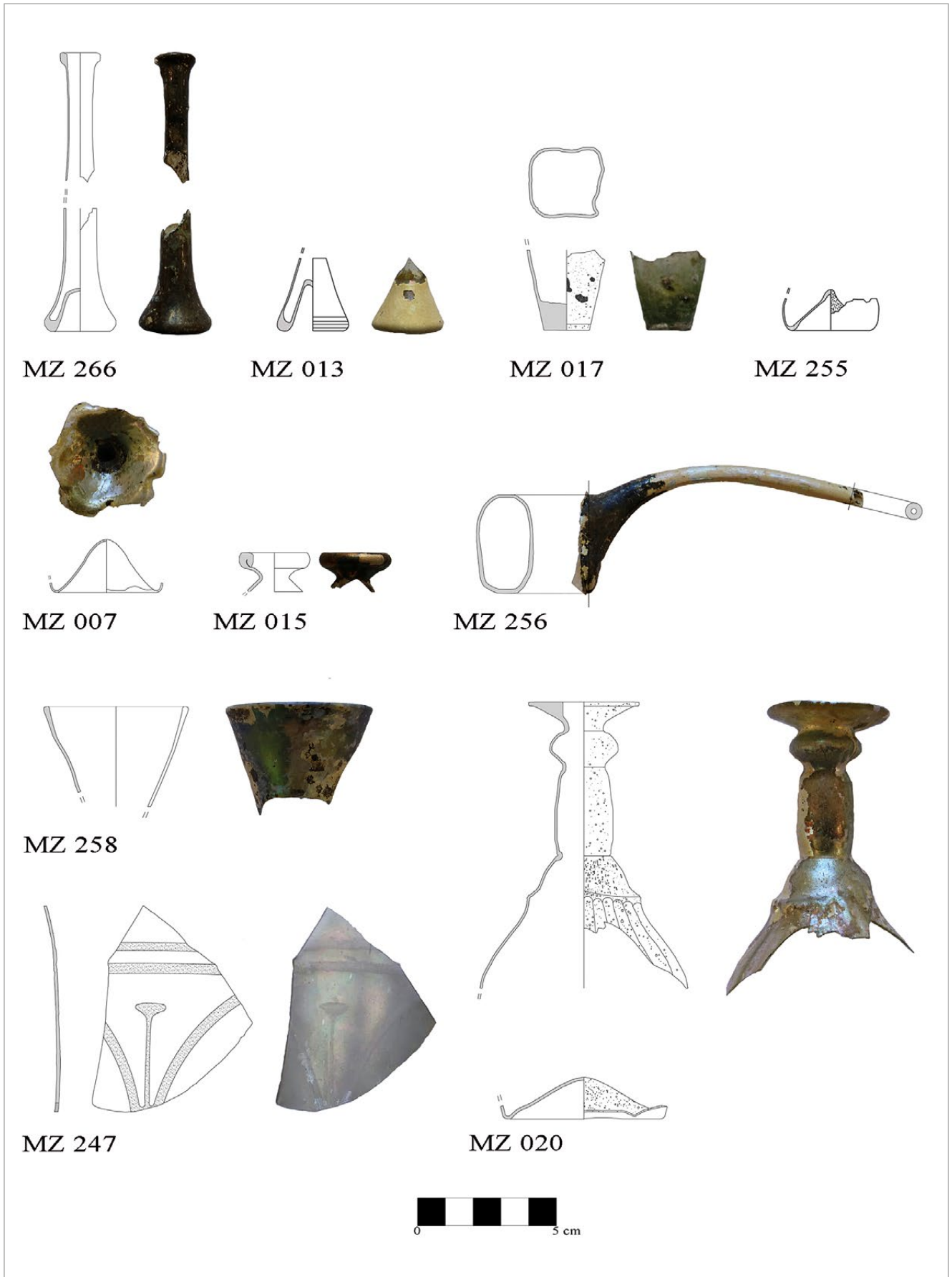


fig. 7 – Vessel types from the Islamic period.

	wt%																	ppm																
	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	Cl	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	Li	B	V	Cr	Co	Ni	Cu	Zn	Ga	As	Rb	Sr	Y	Zr									
MZ014	14.7	0.62	3.04	71.2	0.05	0.79	0.58	8.44	0.06	0.01	0.38	3.26	56.6	6.92	5.48	1.21	5.45	7.60	6.40	3.44	1.60	8.69	440	6.61	36.0									
MZ021	14.5	0.61	3.13	70.8	0.08	0.85	0.56	8.95	0.07	0.01	0.39	3.47	56.3	7.15	6.03	1.24	3.40	3.98	6.72	3.53	1.55	7.94	471	7.11	39.1									
MZ238	14.5	0.58	3.33	70.6	0.05	0.78	0.60	9.00	0.06	0.02	0.36	3.32	70.6	6.71	15.9	1.11	3.36	3.99	6.16	3.57	1.35	9.70	465	6.77	35.4									
MZ239	16.3	0.56	3.19	69.2	0.04	0.98	0.50	8.64	0.06	0.02	0.37	3.17	69.6	6.41	15.5	1.29	3.23	6.59	6.43	3.58	1.30	7.99	469	6.66	33.1									
Byzantine 7 th to 8 th c.	13.6	0.61	3.24	72.5	0.05	0.83	0.42	7.93	0.07	0.02	0.51	3.37	62.1	8.93	20.9	2.41	4.30	4.31	7.28	3.62	1.27	6.64	403	6.56	44.5									
MZ242	14.6	0.69	3.24	69.8	0.05	0.86	0.57	9.61	0.09	0.02	0.40	3.59	59.7	7.21	16.3	1.23	3.49	4.31	6.08	3.51	1.38	7.81	486	6.91	36.6									
MZ243	14.7	0.68	3.23	67.2	0.14	0.76	0.84	11.7	0.08	0.02	0.53	4.16	85.4	9.71	18.8	1.78	4.74	6.77	7.43	3.78	1.21	11.1	479	7.01	41.2									
MZ244a	15.3	0.55	3.20	71.0	0.08	0.99	0.80	7.46	0.07	0.02	0.45	3.83	91.5	8.48	17.5	1.30	3.78	5.53	8.08	3.53	0.94	9.78	401	6.18	37.7									
MZ244b	14.4	0.53	3.26	71.1	0.04	0.94	0.48	8.76	0.05	0.02	0.33	2.51	60.2	5.94	14.1	0.99	2.79	2.80	5.02	3.60	1.14	8.30	474	6.82	31.4									
MZ245	13.0	2.71	1.98	66.0	0.40	0.77	2.24	8.71	0.13	2.58	0.99	25.7	92.2	26.8	15.2	13.7	18.0	72.0	78.6	3.21	7.79	13.4	501	7.30	100									
MZ007	14.0	2.65	1.92	61.2	0.53	0.86	2.40	9.72	0.16	3.10	0.71	33.8	127	14.6	9.50	8.25	14.8	19331	67.6	3.56	60.9	7.00	1060	6.87	175									
MZ011	12.8	1.40	1.94	67.8	0.62	0.98	3.57	7.01	0.13	2.81	0.65	10.3	58.3	18.7	5.25	14.4	13.9	50.2	66.3	3.18	3.64	12.1	602	4.65	117									
MZ012	12.6	1.47	1.73	64.8	0.49	0.97	3.46	9.32	0.16	3.00	1.56	12.6	81.0	44.2	10.6	21.3	73.0	286	63.0	3.36	17.6	9.94	1080	7.84	176									
MZ013	14.9	2.79	2.25	64.2	0.57	0.77	2.16	8.54	0.17	2.24	0.93	53.7	144	18.0	14.5	11.5	11.4	1584	85.6	3.75	7.97	9.02	563	7.07	147									
MZ016	14.6	3.06	2.12	66.1	0.36	0.80	1.79	7.51	0.16	2.31	0.86	53.4	170	14.4	11.8	9.15	11.2	805	73.4	3.52	4.60	9.04	466	6.65	160									
MZ017	15.6	2.96	1.71	69.0	0.28	0.81	1.80	5.94	0.14	1.18	0.36	70.0	222	6.64	8.76	3.22	4.25	13.7	29.2	2.57	1.20	4.80	350	4.85	116									
MZ019	12.7	2.92	2.42	65.3	0.73	0.75	2.37	8.51	0.15	2.42	1.19	36.9	117	26.4	14.7	14.7	18.7	1515	102	4.39	10.9	14.1	485	7.25	126									
MZ020	13.2	3.35	2.11	63.9	0.41	0.81	1.95	8.72	0.14	2.28	0.87	46.5	162	18.0	10.4	11.7	14.0	902	77.1	3.67	9.51	9.91	501	6.32	121									
MZ247	11.5	2.21	1.89	67.8	0.36	0.90	3.35	9.41	0.09	1.65	0.55	3.95	75.9	15.1	19.1	4.22	8.60	46.2	25.3	3.83	1.27	11.6	806	6.40	39.9									
MZ253	14.6	3.04	2.07	66.2	0.38	0.84	1.87	7.59	0.15	2.00	0.83	49.4	180	12.6	25.4	6.63	10.3	1199	56.4	4.30	3.12	8.22	449	6.40	149									
MZ255	13.7	2.92	2.10	65.9	0.50	0.91	2.31	7.87	0.14	2.28	0.90	35.0	162	20.2	30.6	10.2	21.4	870	79.8	5.08	5.40	10.3	562	6.71	118									
MZ256	13.5	2.92	1.98	65.8	0.48	0.90	2.32	8.30	0.13	2.12	0.84	32.5	141	15.5	25.6	7.56	15.5	3407	66.9	4.42	14.6	9.38	583	6.50	112									
MZ258	13.0	2.13	2.24	67.0	0.44	0.82	2.80	8.48	0.14	1.40	1.03	42.0	99.4	20.8	18.1	11.2	12.2	536	118	4.39	8.58	14.4	436	6.36	122									
MZ259	13.5	2.85	2.00	66.1	0.42	0.83	2.42	8.44	0.14	1.94	0.81	32.6	125	16.0	16.0	11.1	15.6	2846	70.9	4.18	15.9	10.5	585	6.76	111									
MZ260	13.6	3.40	2.14	62.4	0.51	0.89	1.72	8.43	0.16	2.31	0.97	59.0	172	19.2	13.7	8.64	28.2	24650	194	4.72	68.8	8.55	516	6.75	155									
MZ261	15.4	2.92	1.53	68.1	0.32	1.14	1.55	7.46	0.11	0.66	0.59	50.0	150	9.80	11.2	3.60	5.68	117	58.2	2.67	1.41	7.80	381	4.58	105									
MZ262	15.2	2.72	2.16	64.7	0.58	0.85	1.99	8.29	0.17	2.09	0.89	48.9	152	17.6	18.0	11.3	10.9	974	70.8	4.21	6.03	7.88	537	7.09	141									
MZ265	14.8	2.70	1.65	66.7	0.47	0.77	1.97	7.19	0.12	2.63	0.74	103	172	10.7	12.1	5.68	8.34	194	54.5	4.06	3.15	7.14	456	5.94	152									
MZ266	14.2	3.17	1.75	65.1	0.62	0.90	2.56	7.71	0.12	2.95	0.60	51.1	159	12.2	14.5	6.01	9.92	1258	65.0	4.36	6.79	9.53	521	5.85	112									
MZ002	18.3	4.26	1.85	62.6	0.50	1.12	1.89	7.99	0.09	0.47	0.78	44.4	176	10.9	8.32	4.35	13.0	54.2	56.9	2.64	1.65	6.39	441	4.00	25.2									
MZ003	12.3	3.32	2.13	67.9	0.53	0.89	1.77	9.19	0.14	0.70	0.92	79.0	164	13.0	11.6	8.87	8.80	22.4	54.6	3.59	3.01	11.2	506	5.38	141									
MZ004	12.0	3.15	2.07	68.4	0.54	0.90	1.76	9.13	0.13	0.75	0.95	68.0	154	13.3	13.9	6.19	7.72	35.4	57.8	3.44	2.17	10.8	509	5.28	133									
MZ005	15.2	2.02	2.25	67.5	0.38	1.02	2.20	7.41	0.14	0.69	1.00	45.2	115	14.1	11.3	12.3	8.01	65.2	62.7	3.56	3.02	13.6	432	5.63	159									
MZ006	12.7	1.71	1.69	67.0	0.29	0.50	1.98	8.42	0.12	4.18	0.90	49.2	91.6	33.0	8.25	5.12	12.6	687	43.4	3.71	6.57	9.99	501	6.09	115									
MZ015	14.1	3.03	1.87	63.2	0.43	0.74	1.98	8.12	0.13	5.40	0.73	115	171	32.6	7.31	14.6	99.8	73.2	63.2	4.20	6.79	6.68	383	8.66	142									
MZ018	12.8	3.32	2.04	67.4	0.49	0.91	1.76	9.22	0.13	0.74	1.00	78.5	168	12.9	13.6	45.5	9.50	105	93.4	3.39	3.09	9.56	519	4.93	126									
MZ240	14.7	2.75	2.51	67.8	0.54	0.97	2.67	6.00	0.14	0.64	1.07	32.4	172	14.8	14.7	6.25	9.31	22.7	69.0	4.13	3.31	17.9	347	6.35	88.0									
MZ241	14.6	2.86	2.52	66.1	0.39	0.95	1.49	7.72	0.17	2.03	0.93	58.1	174	15.2	30.4	6.11	9.88	93.6	53.5	5.31	1.08	6.50	401	6.61	149									
MZ246	14.7	2.74	2.45	68.0	0.53	0.97	2.66	5.97	0.14	0.63	1.04	32.3	169	14.5	14.5	6.14	9.13	22.2	67.0	4.06	3.33	17.8	349	6.26	88.7									
MZ249	14.6	3.28	2.53	64.8	0.39	1.13	1.62	9.58	0.15	0.59	1.09	50.3	164	14.7	15.6	7.84	8.65	48.7	54.4	3.92	2.20	12.5	538	6.14	116									
MZ250	16.0	2.95	1.90	67.9	0.37	0.83	2.15	6.73	0.17	0.21	0.60	48.5	147	6.58	17.1	1.86	3.46	18.1	27.7	3.06	0.28	5.97	372	5.74	183									
MZ251	16.1	1.96	1.67	66.5	0.53	1.25	3.56	7.07	0.16	0.55	0.53	13.3	135	11.2	11.2	7.07	8.59	33.4	79.5	2.74	2.11	16.5	297	5.32	138									
MZ252	11.9	3.32	1.70	66.3	0.36	0.87	2.80	10.7	0.15	0.97	0.64	10.2	101	11.5	8.52	7.92	6.33	23.1	37.0	3.13	2.31	18.9	522	6.34	241									
MZ254	13.4	3.39	0.81	67.6	0.31	0.88	2.88	9.63	0.11	0.37	0.41	10.3	108	7.63	8.73	4.27	10.3	12.2	35.1	1.72	1.36	14.1	503	4.05	158									
MZ263blue	16.9	1.73	3.65	64.8	0.41	0.94	2.36	5.97	0.22	0.49	1.99	22.5	79.2	27.0	19.5	13.7	16.0	1107	428	5.19	6.40	20.2	350	6.56	60.0									
MZ263col	17.7	1.84	3.80	64.9	0.39																													

	Nb	Mo	Ag	Cd	In	Sn	Sb	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Pb	Bi	Th	U
MZ014	1.30	0.29	1.31	0.02	0.00	1.25	0.12	0.08	2.27	6.93	13.0	1.50	6.23	1.23	0.37	1.16	0.17	1.04	0.22	0.60	0.08	0.54	0.08	0.89	0.08	0.05	30.4	0.02	0.76	0.93
MZ021	1.38	0.28	2.83	0.02	0.00	0.65		0.08	2.29	7.22	13.3	1.57	6.46	1.29	0.39	1.24	0.19	1.13	0.24	0.65	0.09	0.57	0.09	1.00	0.08	0.05	3.88	0.00	0.80	0.78
MZ238	1.18	0.25	0.05	0.00	0.75	0.27	0.07	0.07	2.60	6.11	11.6	1.43	6.24	1.30	0.40	1.24	0.18	1.11	0.24	0.66	0.09	0.56	0.08	0.89	0.08	0.05	7.99	0.01	0.74	1.00
MZ239	1.16	0.22	0.07	0.01	0.00	1.24	0.22	0.05	2.36	5.94	11.0	1.39	6.16	1.15	0.39	1.19	0.18	1.12	0.22	0.62	0.09	0.57	0.09	0.86	0.08	0.03	13.3	0.01	0.75	0.68
MZ242	1.45	0.31	0.06	0.00	1.54	0.34	0.04	0.04	2.18	6.20	11.5	1.44	6.16	1.26	0.39	1.16	0.18	1.05	0.23	0.61	0.09	0.57	0.09	1.14	0.09	0.40	14.9	0.01	0.84	0.85
MZ243	1.29	0.28	0.04	0.00	0.00	0.51	0.01	0.01	2.35	6.30	11.8	1.47	6.39	1.33	0.39	1.23	0.19	1.12	0.24	0.63	0.08	0.60	0.09	0.95	0.08	0.04	8.48	0.00	0.77	0.86
MZ244a	1.56	0.42	0.06	0.00	0.77	0.02	0.04	0.04	2.26	6.63	12.2	1.53	6.61	1.32	0.40	1.23	0.19	1.09	0.26	0.65	0.09	0.62	0.09	1.09	0.09	0.06	7.71	0.01	0.88	0.84
MZ244b	1.34	0.42	0.05	0.00	0.33	0.01	0.01	0.01	2.31	5.76	10.7	1.34	5.73	1.18	0.37	1.11	0.17	1.02	0.22	0.58	0.08	0.55	0.08	0.95	0.08	0.04	5.50	0.00	0.80	0.64
MZ245	1.10	0.13	0.05	0.00	0.62	0.02	0.00	0.28	6.11	11.3	14.2	6.04	1.25	0.38	1.16	0.18	1.09	0.23	0.63	0.09	0.58	0.08	0.84	0.07	0.02	8.84	0.01	0.70	0.66	
MZ007	2.54	7.40	0.83	0.11	0.01	42.2	5.29	0.20	50.4	8.92	16.3	1.92	7.41	1.52	0.36	1.30	0.20	1.14	0.24	0.66	0.09	0.63	0.10	2.31	0.15	0.33	101.9	0.10	1.61	0.83
MZ009	2.74	6.61	9.43	0.06	0.00	41.4	10.7	0.08	76.8	9.16	16.7	1.86	7.43	1.44	0.31	1.35	0.20	1.13	0.23	0.65	0.09	0.69	0.11	4.10	0.18	0.34	42.2	1.46	1.89	1.39
MZ011	2.46	8.45	0.13	0.04	0.00	2.74	0.34	0.18	5.22	7.55	13.5	1.46	5.59	1.00	0.23	0.99	0.13	0.72	0.16	0.45	0.07	0.48	0.07	2.80	0.16	0.11	48.9	0.01	1.72	0.77
MZ012	2.72	4.36	0.32	0.12	0.00	11.8	2.70	0.10	4.78	9.88	17.5	2.02	7.92	1.56	0.35	1.52	0.22	1.24	0.27	0.75	0.11	0.76	0.12	4.13	0.18	0.64	516	0.02	1.84	0.94
MZ013	2.96	4.81	1.57	0.08	0.00	54.9	44.8	0.14	15.2	9.35	16.8	1.93	7.75	1.49	0.34	1.46	0.21	1.20	0.25	0.67	0.10	0.69	0.11	3.45	0.18	0.18	3.33	0.16	1.81	1.00
MZ016	2.90	7.72	16.6	0.15	0.02	30.6	21.1	0.14	13.9	9.96	18.5	2.05	8.05	1.55	0.34	1.42	0.20	1.10	0.23	0.65	0.09	0.68	0.11	3.78	0.20	0.20	51.9	0.17	2.04	1.46
MZ017	2.18	4.22	0.18	0.05	0.00	1.85	0.05	0.08	65.7	7.50	14.5	1.66	6.67	1.31	0.28	1.72	0.18	0.87	0.17	0.52	0.07	0.54	0.08	2.82	0.16	0.06	11.8	0.00	1.59	1.03
MZ019	2.72	7.01	69.0	0.11	0.01	58.5	7.23	0.23	27.5	8.67	16.4	1.92	8.09	1.58	0.39	1.20	0.23	1.21	0.25	0.73	0.10	0.73	0.11	3.08	0.18	0.29	170.9	0.29	1.77	1.04
MZ020	2.53	6.35	0.35	0.12	0.00	13.4	6.53	0.15	5.74	8.21	15.6	1.81	7.33	1.44	0.36	1.71	0.20	1.08	0.22	0.63	0.09	0.63	0.09	2.92	0.17	0.30	180.51	0.24	1.65	1.09
MZ247	1.68	2.54	0.10	0.00	0.76	0.02			25.9	6.13	12.1	1.54	6.67	1.42	0.36	1.28	0.20	1.09	0.23	0.56	0.08	0.54	0.08	1.04	0.09	0.31	11.0	0.02	0.86	0.54
MZ253	2.75	7.32	0.81	0.02	0.00	29.1	13.0		11.1	8.94	16.1	1.86	7.33	1.35	0.28	1.19	0.18	1.03	0.21	0.61	0.08	0.59	0.08	3.68	0.20	0.13	583	0.11	2.09	1.22
MZ255	2.54	5.69	1.46	0.07	0.00	24.6	49.6		19.2	8.26	15.3	1.84	7.58	1.43	0.27	1.29	0.19	1.04	0.23	0.61	0.09	0.63	0.10	2.96	0.17	0.29	660	0.08	1.67	1.25
MZ256	2.31	5.27	2.20		0.00	65.6	6.92		18.0	7.67	14.4	1.75	6.93	1.45	0.26	1.19	0.19	1.04	0.22	0.65	0.09	0.61	0.09	2.73	0.15	0.28	626	0.32	1.56	0.94
MZ258	2.95	5.12	0.90	0.13	0.02	11.8	14.5	0.20	32.1	8.66	15.8	1.87	7.58	1.50	0.34	1.13	0.19	1.04	0.22	0.61	0.09	0.64	0.09	2.78	0.19	0.33	205.3	0.11	1.94	0.87
MZ259	2.52	4.65	1.84	0.15	0.03	67.9	4.91	0.13	20.1	7.96	14.5	1.77	7.09	1.40	0.34	1.27	0.20	1.05	0.23	0.62	0.09	0.67	0.09	2.60	0.14	0.29	602	0.19	1.53	0.85
MZ260	3.03	10.0	12.2	0.24	0.12	16.9	36.6	0.07	40.7	9.35	17.8	1.95	7.89	1.57	0.31	1.25	0.19	1.07	0.22	0.63	0.09	0.70	0.11	3.51	0.18	0.31	711	3.60	2.20	1.16
MZ261	2.08	2.75	0.26	0.04	0.00	8.03	0.96	0.13	20.9	6.93	13.1	1.43	5.59	1.05	0.21	0.81	0.14	0.77	0.16	0.45	0.06	0.47	0.07	2.41	0.14	0.07	206	0.01	1.64	1.17
MZ262	2.87	4.89	0.69	0.11	0.02	47.3	43.9	0.09	14.6	8.69	15.3	1.72	7.48	1.46	0.30	1.19	0.21	1.13	0.23	0.67	0.10	0.69	0.09	3.19	0.18	0.13	370	0.09	1.72	0.92
MZ265	2.44	4.60	9.09	0.26	0.01	4.86	0.40		85.0	8.20	15.1	1.74	6.70	1.30	0.22	1.09	0.15	0.88	0.21	0.56	0.08	0.56	0.06	3.56	0.15	0.30	10.9	10.7	1.76	0.71
MZ266	2.18	4.74	2.32	0.07	0.00	38.6	1.36	0.03	13.7	7.34	13.6	1.59	6.39	3.36	0.22	0.98	0.15	0.91	0.18	0.47	0.08	0.53	0.08	2.65	0.16	0.15	167	0.05	1.51	0.71
MZ002	1.60	0.30	0.05	0.03	0.03	2.23	0.33	0.16	10.5	5.55	10.0	1.12	4.32	0.86	0.18	0.70	0.12	0.70	0.13	0.39	0.05	0.37	0.05	0.63	0.11	0.05	13.9	0.04	1.44	0.52
MZ003	2.98	0.32	0.39	0.07	0.22	2.14	0.38	0.28	9.2	7.86	15.2	1.70	6.77	1.31	0.31	1.72	0.19	0.94	0.20	0.54	0.08	0.57	0.08	3.29	0.18	0.34	22.0	0.02	1.74	0.92
MZ004	3.08	0.27	0.09	0.07	0.22	2.14	0.38	0.28	9.34	8.16	15.5	1.73	6.77	1.29	0.29	1.04	0.16	0.91	0.18	0.53	0.08	0.54	0.08	3.05	0.18	0.45	14.0	0.02	1.93	0.94
MZ005	3.30	0.64	0.38	0.08	0.71	6.15	2.67	0.41	11.8	8.78	16.3	1.81	7.07	1.37	0.31	1.46	0.18	1.00	0.20	0.58	0.08	0.61	0.09	3.63	0.20	0.43	35.9	0.04	2.11	0.93
MZ006	2.42	8.15	0.36	0.14	0.02	32.1	4.50	0.19	12.94	8.58	16.3	1.81	7.19	1.35	0.33	1.52	0.18	1.04	0.21	0.60	0.08	0.59	0.09	2.74	0.15	0.21	113.3	0.12	1.77	1.59
MZ015	2.29	14.7	0.22	0.26	0.00	3.36	1.36	0.16	7.56	10.00	16.3	2.07	8.41	1.68	0.42	2.08	0.24	1.35	0.28	0.79	0.11	0.77	0.11	3.34	0.15	0.82	23.2	0.04	1.65	0.73
MZ018	2.81	0.33	0.19	0.07	0.31	9.22	1.46	0.24	9.4	7.34	14.7	1.62	6.30	1.20	0.27	1.56	0.17	0.87	0.18	0.50	0.07	0.52	0.08	2.95	0.17	0.45	52.7	0.07	1.60	0.91
MZ240	3.09	0.29	0.06	0.10	0.07	1.46	0.60	0.55	13.9	9.96	18.5	2.08	8.13	1.55	0.33	1.27	0.19	1.11	0.22	0.60	0.08	0.62	0.09	2.10	0.18	0.29	9.74	0.03	2.45	0.86
MZ241	3.40	9.26	0.26		0.00	5.04	2.94		9.9	9.51	17.5	2.05	8.44	1.74	0.29	1.32	0.21	1.18	0.24	0.67	0.09	0.68	0.09	3.64	0.22	0.08	57.4	0.00	2.23	1.07
MZ246	3.02	0.30	0.06	0.10	0.06	1.39	0.58																							

is a truncated cone beaker with engraved decorations showing columns and arches similar to fragments retrieved from the Serçe Limani shipwreck (*supra* COLANGELI, type I.2).

The thirteenth-century glass typologies instead consist exclusively of tableware, mostly beakers and bottles, but also some goblets (*fig.* 8). Printed beakers are particularly numerous. Printed beakers were popular during the thirteenth century throughout Europe and the Mediterranean, and their comprehensive typological study has revealed that they must have been produced in different workshops (FOY 2014). The Mazara finds include seven printed beakers with some typological as well as compositional variations (*tab.* 1). Two samples were too fragmented to determine a precise typology (MZ 240, MZ249), but their prints are clearly different from the other samples. Four printed beakers (type A) have large barrel-shaped bodies with a flared upper part and several rows of prints. Trails are applied around the body just below the flared upper part as well as at the base. Type A beakers are the most common type known in Italy, from Tuscany (MENDERA 1996, 2004), Rome (RICCI 2002) and Puglia (WHITEHOUSE 1966), and have previously been recorded in Sicily at Segesta, Gela and Palermo (*supra* COLANGELI, type I.4a; FIORILLA 2012; FOY 2014; MOLINARI 1997). One printed beaker (MZ 251) corresponds to Foy type A1 (FOY 2014) and has a narrow cylindrical body, an extensively flared rim and a pinched trail at the base. This type is less common in Italy, but examples are known from Palermo (*supra* COLANGELI, type I.4b; FOY 2014). Other forms identified among the Mazara assemblage are thick, mould-blown beakers with vertical ribs (MZ 267), and a large cylindrical beaker (MZ 252) that flares near the top and that has a foot ring attached around the base (*supra* COLANGELI, type I.3 and type I.5, respectively). The latter shape has been found in some southern Italian, Egyptian as well as Syrian contexts, and is usually painted or enamelled (*supra* COLANGELI, type I.5). The sample from Mazara is plain and thus a cheaper variant of the same typology. Finally, three objects, two bottle necks (MZ 269, MZ 270) and a beaker (MZ 263), are decorated with applied blue trails, similar to some objects from France (FOY 2014, p. 128, *fig.* 1; NEWBY 1991, p. 40).

3. DISCUSSION

The analytical data have established that the vitreous finds from Mazara dating to the tenth and eleventh centuries as well as those from the thirteenth century are consistent with the use of a soda plant ash recipe, and that the two chronological groups are compositionally intimately related. No clear sub-classification of the plant ash glass groups was possible, neither with regard to the plant ash component nor to the silica source. With few exceptions, all plant ash glasses have approximately the same base glass composition. The key characteristics include moderate alumina, alkali and alkaline earth metals, high heavy element concentrations as well as high lithium compared to most other plant ash glass groups known from this period. This raises questions about the provenance of the Mazara glass and whether there are comparable glass compositions from other early Islamic sites. The question of the origin of the Mazara glass ties into the broader issue of the development of the soda ash glass industry in the western Mediterranean.

COMPOSITIONAL LIKENESS TO OTHER SODA ASH GLASS TYPES

Trying to establish compositional similarities between glass assemblages is a rather complex issue, but by way of elimination some possibilities can at least be excluded with relative certainty. We compared the compositions of the Mazara plant

ash glass to published data from plant ash glass assemblages of Levantine, Egyptian and Iberian origins, particularly in relation to elements that are related to the silica source such as titanium and zirconium. Titanium and zirconium are usually highly correlated, and eastern Mediterranean as well as early Islamic Iberian plant ash glasses distribute along a similar zirconium to titanium regression line (*fig.* 9a). In contrast, the samples from Mazara clearly deviate, exhibiting higher zirconium relative to titanium concentrations that reflect the use of different raw materials and by extension a different geological and geographical source of the silica component. The singularity of the Mazara glass finds is evident when comparing the ratios of thorium to zirconium and lanthanum to titanium that separate different regional plant ash glass groups (*fig.* 9b). Due to the relatively high concentrations of zirconium, the majority of the Mazara samples has the lowest Th/Zr ratios setting them apart from all other regional groups, in spite of overlapping La/TiO₂ ratios. The output from Tuscan workshops dating to the thirteenth and fourteenth century do not provide a match for the Mazara samples either, as the Tuscan glasses have much higher thorium to zirconium ratios (CAGNO *et al.* 2012a; CAGNO *et al.* 2012b; CAGNO *et al.* 2008; POSEDI *et al.* 2019).

Since the exact combination of compositional features of the Mazara plant ash glass has not been encountered anywhere else in the Mediterranean region, the raw materials must have originated from a yet unknown primary production location. It is therefore reasonable to assume that the glass derived from a regional, perhaps Sicilian silica source that is characterised by a high zirconium content relative to the other traces and REEs. A regional production is also supported by the fact that there are no marked differences between the two chronological groups from Mazara, which suggests a certain continuity in the supply and by extension in the manufacture of glass, in spite of fundamental geopolitical changes that are reflected in the different typological repertoires. Some modifications occurred with respect to the addition of manganese and the degree of recycling, both of which are significantly lower in the thirteenth-century group. Notable manganese contents are usually present in early Islamic glass finds (SWAN *et al.* 2017, and references therein). The decrease in manganese concentrations in the thirteenth century may thus reflect a changing socio-economic landscape in Sicily that had since come under Swabian occupation.

There are some exceptional objects among the plant ash glasses from Mazara. As mentioned before, sample MZ 247 exhibits very different trace element patterns with significantly lower heavy element concentrations relative to the REEs. This fragment has a compositional signature very close to the glass from the primary production site of Tyre (FREESTONE 2002) and may have been imported from the Levantine coast as finished object. Examples of early Islamic Levantine plant ash glass have turned up around the entire Mediterranean littoral, in Spain (DE JUAN ARES *et al.* 2021), southern France (unpublished), and the Italian Peninsula (BERTINI *et al.* 2020; NERI *et al.* 2019). Large shipments of Levantine plant ash glass arrived in Egypt (SCHIBILLE *et al.* 2019) as well as Asia Minor (BRILL 2009), indicating that Levantine plant ash glass was traded widely during the tenth and eleventh centuries. Another of the Mazara samples (MZ 002) has very high thorium to zirconium ratios, coupled with relatively high soda and magnesia values. This may be a fragment of Iberian glass (DE JUAN ARES, SCHIBILLE 2017; DE JUAN ARES, SCHIBILLE under review). Two of the thirteenth century cobalt blue samples also exhibit different base glass compositions. Their cobalt signature corresponds to a European cobalt source, possibly located in the area of the Erzgebirge in central Europe that was exploited since



fig. 8 – Some examples of Swabian context glasses.

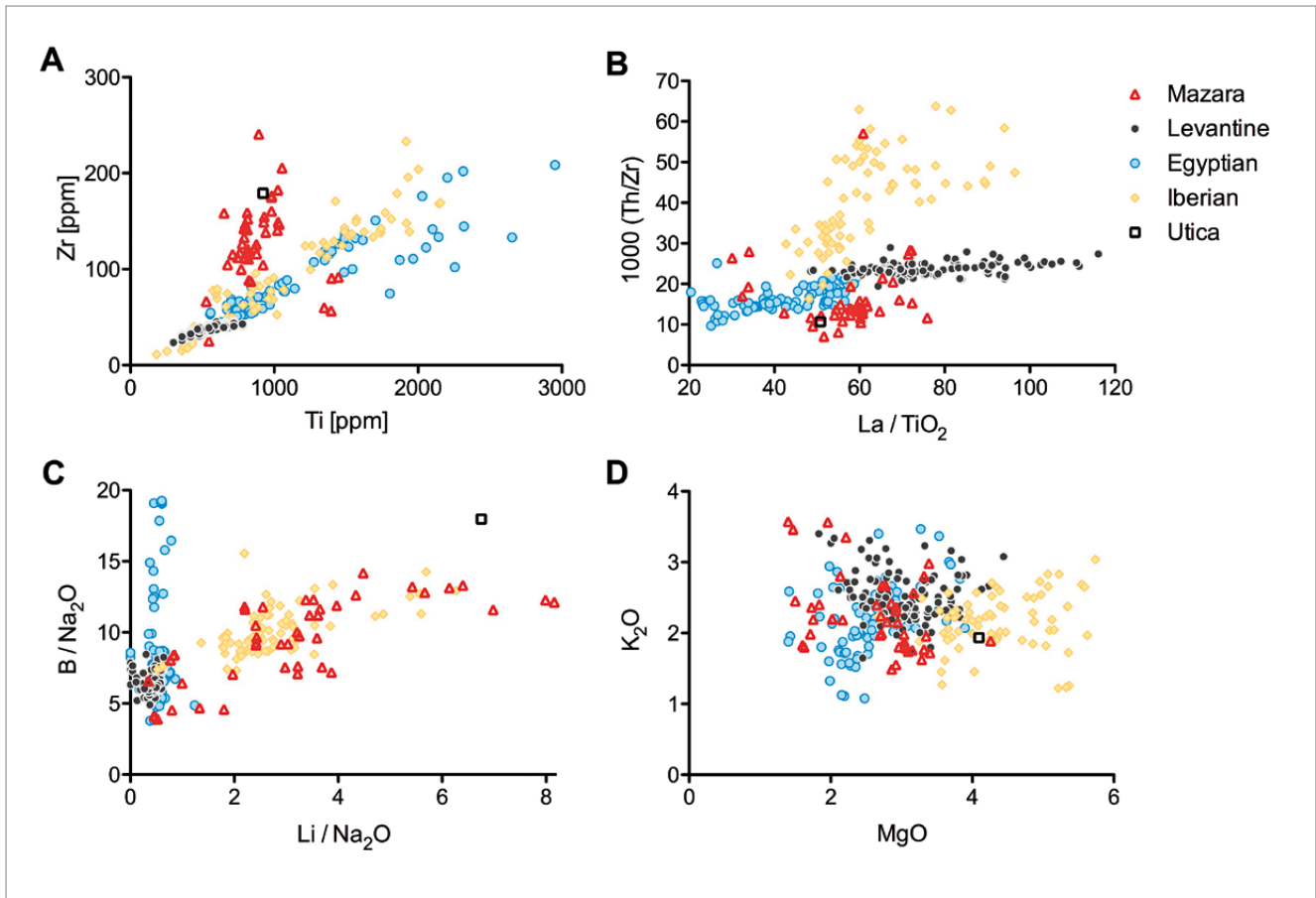


fig. 9 – Comparison of the Mazara plant ash glass with published data of early Islamic glass assemblages from the Levant, Egypt and the Iberian Peninsula. (a) Zirconium and titanium contents reflect the silica source and highlight the compositional differences of the Mazara samples; (b) thorium to zirconium ratios clearly separate the Mazara glass from all other regional groups, while they overlap to a certain extent in terms of their lanthanum to titanium ratios; (c) lithium and boron normalised to soda levels demonstrate the peculiar nature of the plant ash component of the Mazara samples that closely resembles that of early Islamic glasses from the Iberian Peninsula; (d) Spanish plant ash glass has on average higher magnesia levels than all other early Islamic soda-rich plant ash glasses. Data sources: (SCHIBILLE *et al.* 2019) (Egyptian); (PHELPS 2017, PHELPS 2018) (Levantine); (DE JUAN ARES, SCHIBILLE 2017) (Spain).

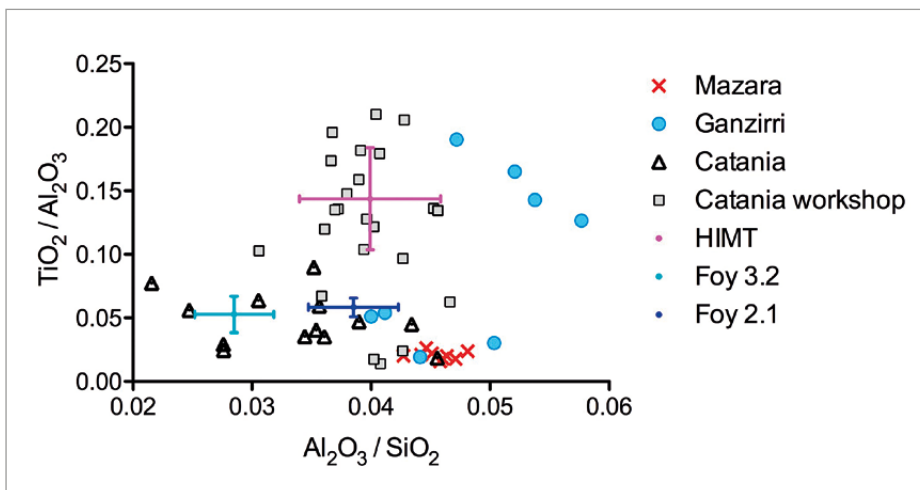


fig. 10 – Comparison of the seventh- and eighth-century glass from Mazara with published data of Roman and late antique natron type glass finds from other Sicilian sites. Data sources: (ARLETTI *et al.* 2010; BARBERA *et al.* 2012; DI BELLA *et al.* 2015) (Sicilian); (CEGLIA *et al.* 2019; DE JUAN ARES *et al.* 2019b; FOSTER, JACKSON 2009; FREESTONE *et al.* 2018) (HIMT); (CEGLIA *et al.* 2019; FOY *et al.* 2003; SCHIBILLE *et al.* 2016) (Foy 2.1); (BALVANOVIĆ *et al.* 2018; CHOLAKOVA, REHREN 2018, FOY *et al.* 2003; GALLO *et al.* 2014; MALTONI *et al.* 2015) (Foy 3.2). Error bars illustrate the standard deviations where means are given.

the thirteenth century CE (BIDEGARAY, POLLARD 2018; GRATUZE *et al.* 2018; GRATUZE *et al.* 1992; GRATUZE *et al.* 1996). These two beakers may have been imported as finished objects, however, no close match has yet been identified. The third fragment decorated with a cobalt blue glass is of the Mazara plant ash composition, whereas the cobalt colourant is again associated with an increase

in zinc, indium and lead akin to a European cobalt source. This implies that the cobalt colourant may have been traded separately to be used in Sicilian workshops.

Raw materials for glass production are known to have frequently been traded over long distances. For instance, soda ash used for the production of glass in Italy from the twelfth

or thirteenth century onwards was imported from either the Levantine coast or the Iberian Peninsula (CAGNO *et al.* 2008; POSEDI *et al.* 2019). Plant ash from these two regions typically results in different glass compositions. Most notably, Spanish *barilla* is said to be richer in potassium oxide ($K_2O > 4.5\%$) than Levantine plant ash ($K_2O < 3.5\%$) (CAGNO *et al.* 2008; FREESTONE 2006; POSEDI *et al.* 2019; SCHIBILLE *et al.* 2018). There is some mention of the trade of plant ash for the use in soaps in Iberia as early as the ninth century (GÓMEZ 1957), and plant ash glassmaking appears to be fully established in Spain by the tenth century (DE JUAN ARES, SCHIBILLE 2017; SCHIBILLE *et al.* 2020). Early Islamic plant ash glasses from Iberia have distinct compositional characteristics, including a peculiar plant ash component with elevated lithium and boron similar to the glass from Mazara (*fig.* 9c). However, Spanish plant ash glasses tend to have higher magnesia and soda concentrations (*fig.* 9d). This means that the import of soda-rich plant ash from the Iberian Peninsula to Sicily cannot be confirmed.

Concerning the sub-category of the thirteenth-century Mazara glass that contains lower alkaline earth metals, the plant ash may have undergone a purification process to remove the less soluble compounds such as magnesium, calcium and phosphorus (CAGNO *et al.* 2012a; MCCRAY 1998; POSEDI *et al.* 2019; VERITÀ, ZECCHIN 2009). Purification of plant ash is thought to have been practiced in the production of glass in northern Italy in the thirteenth century and later, certainly in Venice, but also in Liguria and Tuscany (CAGNO *et al.* 2012a; CAGNO *et al.* 2012b). It is interesting to note that the glass from the Islamic period of Mazara does not show any signs of purification and only the plant ash for some of the thirteenth-century samples may have undergone some treatment. This suggests a chronological shift in the preparation of the raw materials destined for specialised glass productions. Given the enormous variability of plant ashes (BARKOUDAH, HENDERSON 2006), however, it is difficult to estimate the real extent of ash purification and/or what impact different purification techniques may have had on the final glass composition.

TEMPORAL AND REGIONAL DEVELOPMENTS

The compositional structure of the Mazara assemblage highlights temporal developments in the supply of glass to Sicily. The comparison with published data of Roman and late antique glass assemblages from other Sicilian sites (*fig.* 10) provides a glimpse into shifting trade networks between the fifth/sixth century and the late seventh century. Previous studies on Sicilian natron type glass assemblages identified predominantly Egyptian glass groups. Fourth- to fifth-century HIMT glass, for example, prevailed in the secondary glass workshop in the Roman amphitheatre of Catania (DI BELLA *et al.* 2015) as well as at the village of Ganzirri north of Messina (ARLETTI *et al.* 2010). The slightly later Foy 2.1 compositional group (second half of fifth and sixth century), also of Egyptian origin, was discovered in Ganzirri and at the church of St Agata la Vetere in Catania, where some Egyptian Foy 3.2 specimens were also found (BARBERA *et al.* 2012). Only three Roman samples of a likely Levantine origin were among the finds from the workshop at Catania; they appear to correspond to the Roman manganese decoloured and Roman naturally coloured category (DI BELLA *et al.* 2015). Altogether, three Apollonia type Levantine I compositions were identified among the finds from Ganzirri and the church of St Agata, the latter sample dating to the late eighth century CE.

Even if the currently available data of glass assemblages from late antique and medieval Sicily remain limited, it can be

concluded that most of the glass consumed on the island in the fourth to sixth century was Egyptian. Judging from the Mazara glass finds the only glass group in the late seventh and eighth century is Apollonia type Levantine I. By the late seventh century, raw glass produced on the Levantine coast has seemingly replaced Egyptian glass as the main source of supply in Sicily. Similar observations have been made with respect to glass assemblages from Visigothic Spain, where there is evidence that this shift took place in the second half of the sixth century CE (DE JUAN ARES *et al.* 2019a). What motivated this development is difficult to explain. The reason could be at the source itself, insofar as the extent of primary glass production in Egypt during the seventh century remains uncertain. Alternatively, maritime trade networks may have changed on a regional as well as inter-regional scale at the time. In the eighth century, Egypt once again exported large quantities of glass, this time almost exclusively to the Levant (ADLINGTON, RITTER, SCHIBILLE 2020; PHELPS *et al.* 2016). The eighth- and ninth-century glass groups known as Egypt 1 and Egypt 2 have only sporadically been found in the western Mediterranean (NERI *et al.* 2019), suggesting that the long-distance bulk exchange of vitreous materials by that time was severely reduced.

The most important outcome of our study is that the composition of the tenth- to thirteenth-century plant ash glasses from Mazara does not correspond to any known eastern Mediterranean, Iberian or in fact Italian assemblage, whereas a substantial number of contemporary glass finds from other Sicilian sites like Castello della Pietra, Castronovo area, the Islamic village built on the remains of the Villa del Casale and six contexts located in different neighbourhoods of Palermo exhibit the same distinct compositional characteristics, suggesting a new, possibly local/regional primary production group¹. The compositional makeup of a single tenth-century glass fragment from Utica (Tunisia) seems to be almost identical to the Mazara plant ash glass both in terms of the silica as well as the compositional features of the plant ash component (*fig.* 9). Typologically, the Islamic finds from Mazara bear some resemblance with the glass from Şabra al-Manşūriya (Qayrawān, Tunisia), where archaeological remains point to the primary production of raw glass (Foy 2012, 2017, 2020). Qayrawān was an important cultural and political centre in the ninth to eleventh centuries, and it may therefore be argued that raw glass was more likely manufactured in north Africa rather than in Sicily. In line with this interpretation, the excavations at Mazara yielded Tunisian ceramic ware from tenth-century as well as thirteenth-century contexts. Furthermore, none of the sand sources from Sicily analysed by Degryse (2014) have compositions suitable for producing glass with the characteristics of the Mazara plant ash glass. However, together with Tunisian imports local ceramics and ware from Palermo have also been found. Recent investigations of pottery from Palermo have identified local ceramic productions that show close similarities with some Tunisian ones, such as the yellow Raqqāda and yellow Palermo pottery attested by the end of the ninth or first decades of the tenth century. The absence of experimentation and the presence of locally produced glazed ceramics of high quality from the very beginning in the ninth century points to the arrival in Sicily of skilled craftsmen (SACCO 2017). It is quite conceivable that this

¹ These contexts were studied from both typologically and archaeometric point of view within the PhD research “*The reflection of glass and metals: beyond the pottery for the understanding of cultural and economic changes. The case of Sicily in the 6th-13th centuries*”, conducted by F. Colangeli at the University of Rome “Tor Vergata” with the collaboration of ERC projects “*Sicily in transition*” and “*GlassRoutes*”.

also applies to the development of glass production in Sicily. Written sources from the fourteenth century show that Sicily was known for both good quality sand that was exported to Venice as well as halophytic plants (D'ANGELO 1991). Finally, the fact that the typological repertoire of the glass assemblage from Mazara changed radically from the eleventh to the thirteenth century, while the base glass composition remained largely unchanged, favours a Sicilian production.

CONCLUSION

The analytical investigation of the archaeological glass assemblage from Mazara reveals broad temporal developments in economic and technological activities over the long term, highlighting periods of transformation and differences between regional traditions. Byzantine natron type glass was imported from the Levantine coast, as was generally the case in the western Mediterranean, which proves that the long-distance maritime connections were still intact. For the Islamic period, the analytical data suggest a marked contrast between Sicily and the Italian Peninsula, where recycling of old natron glass was the main source of supply during the latter part of the first millennium CE. Towards the end of the first millennium CE, glass is not a very common material in the archaeological record of Italy and its presence is usually associated with ecclesiastical, monastic or aristocratic contexts (*supra* COLANGELI; CASTELLI 2020; FERRI 2018; DI MURO 2017; DEL VECCHIO 2002). In contrast, Sicily appears firmly integrated into the Islamic sphere of influence, which is mirrored in the circulation and possibly even the production of soda-rich plant ash glasses in line with the Islamic tradition. The glass assemblage from Mazara reflects technological and typological features common elsewhere in the Islamic world. However, the glass itself exhibits distinct compositional features that indicate a regional glass production, possibly in Sicily itself.

Ultimately, our compositional and typological study of the Mazara glass supports a model for the transformation of the supply of glass to the island of Sicily and the possible establishment of a new indigenous primary glass production for a predominantly local or regional market. Soda-rich plant ash glass first appears in the archaeological context of Mazara during the Islamic period, at a time when the production of glass using soda ash as principle fluxing agent was firmly established in the Islamic world from Central Asia to the Iberian Peninsula. It is thus highly probable that this Islamic glassmaking technology was transferred to Sicily from other Mediterranean areas. Our data fit seamlessly into general observations about the adoption of plant ash glassmaking in the medieval Mediterranean that imply a reduced scale of production and thus a greater diversity of glass compositions. Once established, this glassmaking tradition survived political and cultural upheavals and Sicily's integration into the European fold (the *spätzle connection*). In the absence of more precise geological and/or archaeological evidence for a local or regional glass production in Sicily, however, this model remains tentative.

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Il Progetto *The Archaeology of Regime Change. Sicily in Transition. 6th-13th centuries* (SICTRANSIT – ERC advanced grant 693600) ha consentito di studiare con un'ampia gamma di analisi archeologiche e scientifiche il prezioso contenuto di fosse, pozzi, latrine e silos scavati nel 1997 nel centro storico della città di Mazara in Sicilia. La ricchezza e diversità dei materiali ritrovati, l'integrità dei contesti di rinvenimento e la loro scansione cronologica (dalla fine del VII al XVI secolo) si sono rivelate preziose per ricostruire consumi, scambi, produzioni, abitudini alimentari, tabù religiosi in relazione a importanti cambiamenti sociali e culturali che hanno interessato la Sicilia col passare delle dominazioni bizantina, musulmana, normanna, sveva e aragonese. Le vicende materiali di Mazara, seconda città dopo Palermo per importanza in età islamica e influente sede vescovile con i Normanni, acquistano nuova luce con una lettura dal basso, a partire dai più umili resti della vita quotidiana. La rilevanza dei risultati ottenuti per questa importante città, ha consentito di allargare, rivedere e completare la conoscenza non solo della Sicilia medievale, ma per molti versi anche dell'area mediterranea centrale tra la fine dell'antichità e quella del medioevo.

The project *The Archaeology of Regime Change. Sicily in Transition. 6th-13th centuries* (SICTRANSIT – ERC advanced grant 693600) has made it possible to study with a wide range of archaeological and scientific analyses the contents of pits, wells, latrines and silos excavated in 1997 in the historic centre of the city of Mazara in Sicily. The richness and diversity of the materials found, the integrity of the contexts in which they were unearthed and their chronological span (from the end of the 7th to the 16th century) proved invaluable in reconstructing consumption, trade, production, food habits and religious taboos in relation to the important social and cultural changes that affected Sicily through the periods of consecutive Byzantine, Muslim, Norman, Swabian and Aragonese government. The material history of Mazara, the second most important city after Palermo in the Islamic period and an influential bishopric under the Normans, is here illuminated from the bottom up, starting from the most humble remains of daily life. The relevance of the results obtained for this important city has made it possible to broaden, revise and enhance our knowledge not only of medieval Sicily, but in many ways also of the central Mediterranean area between the end of antiquity and the later Middle Ages.

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