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Glass trade through the Adriatic Sea: preliminary report of an ongoing project

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ABSTRACT

A repertoire of 1357 glass samples from Italy, Croatia, Slovenia and Serbia was used to investigate glass trade in the Adriatic Sea. The achieved overview begins in the 1st century and, after a peak of occurrences between the 4th and the 7th century, continues until the 16th with a decreasing number of pieces of evidence.

Between the 1st and the 3rd century, Levantine (Roman Mn) and Egyptian (Roman Sb) products coexist in percentages that can be considered comparable at the current state of studies. The end of the 3rd and the beginning of the 4th century mark a substantial decrease in Levantine imports. Indeed, Jalame-type glass first and *Apollonia*-type glass later appear to supply a small slice of the market. Egyptian products, on the contrary, continue to arrive in abundance. The HIMTa and the Foy Série 2.1 glass represent the most widespread products in the Adriatic area for about three centuries. Conversely, the Foy Série 3.2 experiences flowering in northern Italy, Slovenia and Serbia, while it shows limited diffusion in southern Italy, as well as in Tyrrhenian Italy, Sicily or other areas of the Mediterranean basin such as Spain. Based on this observation, it thus seems reliable to exclude Foy Série 3.2 glass from the basket of products typically marketed in the Adriatic Sea (*i.e.* Levantine products and Egyptian products of types HIMTa-b and Foy 2.1). In this case, a Balkan route may appear possible because it covers the territories where the most significant diffusion of this glass has been observed and is well connected to northern Italy through the Danube and Sava rivers. In southern Italy, the need for more data on the oldest productions prevents a reliable evaluation of Roman Mn and Roman Sb glass imports and highlights a line of research to be pursued in the immediate future.

1. Introduction

This study represents a first synthesis effort within the projects FOOD & S.T.O.N.E.S. and CHANGES, funded by the Italian Ministry of University and Research. For about a year and a half, the project has brought together the teams of three Italian universities (Bari 'Aldo Moro', Foggia and Venezia 'Ca' Foscari') to examine the production and distribution of different types of materials - from ceramics to sarcophagi- in the Adriatic Sea. An essential branch of this project concerns glass found in several archaeological sites, both in northern and southern Italy.

Up to now, three new glass collections from as many archaeological sites have been fully characterised: *Salapia* and *Canusium* in southern Italy and Jesolo in northern Italy. The 41 samples from *Salapia* have been recently published and consist exclusively of glassware (10 beakers/lamps, 7 chalices, 1 cup, 3 cups/plates, 6 jugs/bottles, 7 lamps and 7 wall fragments), dated between the 3rd and the 7th c. CE (Gliozzo et al., 2023a). In this case, research interests lay in investigating glass provenance in a port site that had long represented a crucial commercial node in the southern Adriatic area (Gliozzo et al., 2019b).

The 38 samples from *Canusium* are currently unpublished and concerned vessels (4 beakers/lamps, 9 goblets, 4 jugs/bottles and 20 lamps) and production indicators (1 chunk), dated between the 4th and the 9th c. CE. The town of *Canusium* was one of the leading centres in Roman and late antique *Apulia;* therefore, the research focused on an urban site which further revealed traces of secondary glass processing.

With the third collection, the focus shifts to the northern Adriatic coast and, more precisely, to the ancient mansio of *Equilus* (Jesolo) in the Venetian lagoon. This new collection is the most numerous and heterogeneous: 67 glass samples dated between the 4th and the 12th c. CE, including 1 base, 19 beakers, 4 blocks, 10 goblets, 3 cups, 4 filament, 4

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lamps, 5 *tesserae*, 8 wall fragments and 9 windows. The discovery of production indicators could indicate the presence of a local workshop; however, the commercial vocation of the site suggests reconstructing the on-site exchange of semi-finished products as more likely (Gliozzo et al., 2023b).

All collections have been (/will be) investigated by electron microprobe (EMPA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). In addition, a smaller selection of samples has been further submitted to Sr-Nd isotopic analyses.

The overall research objectives are manifold but substantially divided into two levels. The first level is represented by the case studies and consequently focused on providing new information on the economy of each archaeological site. The second level represents this contribution's main topic and aims to reconstruct the circulation and production of late antique and early medieval glass in the Adriatic area. This broad research framework made it necessary the provenance reassessment of "old" data in light of the current reference groups. Precisely this reassessment represents the most challenging issue of all this research and, for the moment, it has been done for a total of 1357 analysed glass samples. In this regard, it is worth underlining that not all available data have been processed so far; therefore, the results presented here must be considered preliminary, although already meaningful.

2. Data mining – Selection criteria and provenance assessment

The samples to be used for the construction of the reference database were selected based on four criteria:

(1) the place of discovery - necessarily included in the commercial influence area of the Adriatic Sea (Fig. 1);
(2) the type - including vessels and windows while excluding architectonic (*tesserae* and *sectilia*) and ornamental glass (beads and bracelets);
(3) the natron-based composition - using MgO and K_2O values less than 1.5 wt% as cut-off limits, with sporadic exceptions;
(4) the chronology - using the "oldest chronology" parameter set at $\leq 13^{th}$ c. AD. Based on this criterion, for example, a vessel dated to the 13^{th}-16^{th} c. was included while one dated to the 14^{th}-16^{th} c. was omitted.

Data were collected from fortysix papers: (Arletti et al., 2008, 2010; Drauschke and Greiff, 2010a; Genga et al., 2008; Salviulo et al., 2004; Santagostino Barbone et al., 2008; Silvestri, 2008; Silvestri et al., 2005, 2008; Verità et al., 2002; Zucchiatti et al., 2007; Križanac, 2009; Drauschke and Greiff, 2010b; Fiori and Vandini, 2010; Gallo and Silvestri, 2012; Ganio et al., 2012a; Silvestri and Marcante, 2011; Ganio et al., 2012b; Fiori, 2013; Gallo et al., 2013; Šmit et al., 2013a; Gallo et al., 2014; Gallo et al., 2015; Jackson and Cottam, 2015; Maltoni et al., 2015; Stamenković, 2015; Stojanović et al., 2015; Boschetti et al., 2016a, 2016b; Gliozzo et al., 2016a,b; Maltoni et al., 2016; Boschetti et al., 2017; Coutinho et al., 2017; Balvanović et al., 2018; Cottam and Jackson, 2018; Gliozzo et al., 2019a,b; Neri et al., 2019a, 2019b; Balvanović and Šmit, 2020; Bertini et al., 2020; Milavec and Šmit, 2020; Pactat et al., 2021; Balvanović et al., 2022; Gliozzo et al., 2023a and Gliozzo et al., 2023b).

The 1357 vessels collected from the publications listed above come from 45 sites: 24 Italian (1025 samples), 3 Slovenian (60 samples), 8 Croatian (74 samples) and 10 Serbian (198 samples).

The distribution map in Fig. 1 highlights the presence of either concentrations or extensive areas not covered by glass studies. This information must be taken into high consideration. Indeed, the existing gap weakens the reconstructions that will be proposed as well as highlights the urgency of starting systematic study campaigns on the northeastern Adriatic coast. It should also be noted that glass from Albania, Greece and other countries, such as Hungary and Romania, were omitted; however, they will soon be added in the continuation of this research. In particular, the numerous glass finds from Albanian sites are crucial for understanding Adriatic trades; therefore, a brief mention will also concern the materials labelled from "a" to "g" in Fig. 1.

Similar to the geographical distribution, the chronological coverage is not homogeneous (Fig. 2) and partially reflects the different fortune that natron-based glass collected over the centuries. Moreover, many samples are dated over considerable periods that can even reach six centuries. Fig. 2 shows the quantifications by period if the most recent (left) or oldest (right) date is taken into account. In both cases, the period ranging from the 3^{rd} to the 7^{th} c. is the most significant. However, in the first case, the frequency fluctuates, showing a higher abundance in the 3^{rd}, 5^{th} and 7^{th} c. Conversely, a progressive decrease from the 3^{rd} to the 7^{th} c. is noted in the second case. Undoubtedly, these uncertain dates affect the overall results but there is no way to define the range better.

The most recent finds, which can be dated up to the 16^{th} c., are scarcely representative but have been included because they satisfy the three requirements adopted for the creation of the database and, in many cases, their datings are wide, thus suggesting that they can be older (*e.g.*, Nogara samples dated by the authors to the 9^{th}-16^{th} c.).

Regarding the compositional comparison with the reference groups, four different assignment levels corresponding to as many uncertainty levels were used to eliminate - as much as possible - controversial cases. The primary groups used are believed to be of Levantine (*Apollonia*, Jalame, Bet Eli'ezer and Roman Mn) and Egyptian origin (HIMTa-b, Foy Série 2.1, 2.1 high Fe and 3.2, Roman Sb and the Egypt series).[1]

Notwithstanding the rigidity of this bipolar attribution, it is still functional to outline some general considerations. Other references used are represented by Foy 2.2 -intended as an intensely coloured variant of Mn-poor Foy 2.1- and the Roman Mn-Sb because they indicate glass mixing and deliberate additions. Furthermore, an attempt has been made to distinguish Roman Mn-Sb glass from mixtures of Foy 3.2 and Roman Sb glass. Indeed, glass containing high levels of manganese and antimony is generally classified as Roman Mn-Sb, thus implying a combination of Levantine (Roman Mn) and Egyptian (Roman Sb) glass. Conversely, a mixture of Foy 3.2 glass with Roman Sb may result in a glass similar to Roman Mn-Sb but, according to currently applied provenance conventions, of Egyptian origin. However, some perplexities arise regarding the origin and trade of Foy 3.2 and this topic will be explored in the last section of this contribution.

Going back to the provenance assessment of these 1357 specimens, they were designated as follows:

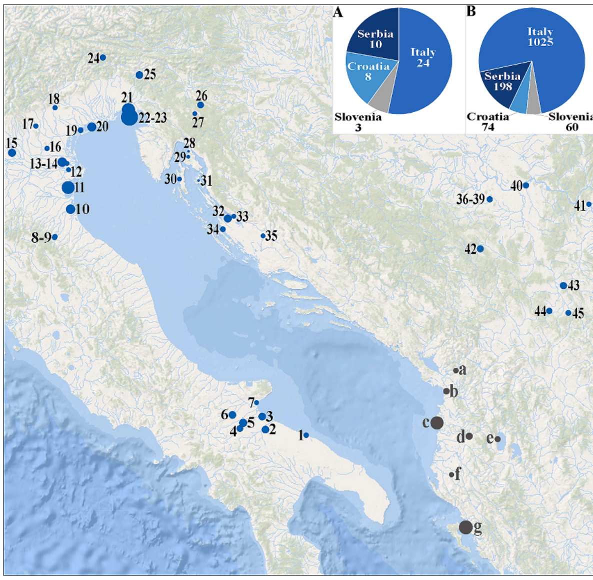
(1) *stricto sensu* (*s.s.*)- when strictly compatible with the "fresh" reference group. The latter was obtained by excluding from the "total" group (a) all outliers identified by T-test and (b) all samples with Co, Cu, Sn, Sb and Pb values > 20 ppm. "Strictly compatible " means that all major elements (SiO_2, TiO_2, Al_2O_3, FeO, MnO, MgO, CaO, Na_2O and K_2O), colouring agents (Co, Cu, Sn, Sb, Pb) and Sr and Zr values of the sample fall within the minimum–maximum limits of the "fresh" group;

(2) *total* - when reliably compatible with the "total" reference group (*i.e.* "fresh" + recycled/coloured materials) on the basis of all values and ratios listed at point 1. Groups composition is calculated from the following literature data: Brill (1988), Mirti et al. (1993), Freestone (1994), Henderson (1999), Freestone et al. (2000), Foy et al. (2003), Foster and Jackson (2009), Rehren and Cholakova (2010), Rosenow and Rehren (2014), Ceglia et al. (2015), Smith et al. (2016), Cholakova and Rehren (2018), Rosenow and Rehren (2018), Schibille et al. (2019), Schibille (2022). The average values are provided in Supplementary Tables 1–6;

(3) *similar* - when likely compatible with the "total" reference group based on FeO/TiO_2, Al_2O_3/SiO_2, TiO_2/Al_2O_3, CaO/Sr and Zr/Hf ratios.

(4) *mixed* - if none of the cases above applies. In this case, however, when a vague similarity with a reference group or an overall

[1] Hereafter, these groups are referred to as "Foy 2.1″, "Foy 2.2" and "Foy 3.2".



Country	Site no.	Site	Samples tot.
Italy	1	Bari	14
	2	*Canusium*	38
	3	*Salapia*	41
	4	Faragola	32
	5	*Herdonia*	46
	6	San Giusto	38
	7	Siponto	7
	8	Mevaniola	10
	9	Galeata	13
	10	Classe	70
	11	Comacchio	101
	12	Ariano Polesine	4
	13	Corte Cavanella	3
	14	Adria	60
	15	Nogara	56
	16	Monselice	8
	17	Pedemure S. Biagio	13
	18	Rocca di Asolo	8
	19	Torcello - square	18
	20	Jesolo	67
	21	Aquileia	161
	22	Fumolo-Grado	26
	23	*Iulia Felix*	172
	24	San Martino di Ovaro	19
Slovenia	25	Tonovcov grad	39
	26	Korinjski hrib	19
	27	Ribnica	2
Croatia	28	Mirine-Fulfinum	5
	29	Cickini	8
	30	Martinšćica	22
	31	Supetarska Draga	2
	32	Podvršje	19
	33	Starigrad	2
	34	Zadar-Nin	15
	35	Ivoševci (*Burnum*)	1
Serbia	36	Reka necropolis	4
	37	Rt necropolis	2
	38	Gomilice necropolis	10
	39	Stojnik castrum	17
	40	*Viminacium*	25
	41	*Egeta*	11
	42	Gradina - Jelica	50
	43	Medijana	38
	44	Caričin Grad	24
	45	Mala Kopašnica	17
Albania	a	Komani	6
	b	Lezha	20
	c	Durrës	111
	d	Elbasan	33
	e	Lin	11
	f	Byllis	4
	g	Butrint	124

Fig. 1. Map showing the sites considered in this study. In the table, the quantification of the materials is provided from each site. The pie charts show the number of sites (A) and samples (B) investigated for each country. [Site no. refers to map's numbering].

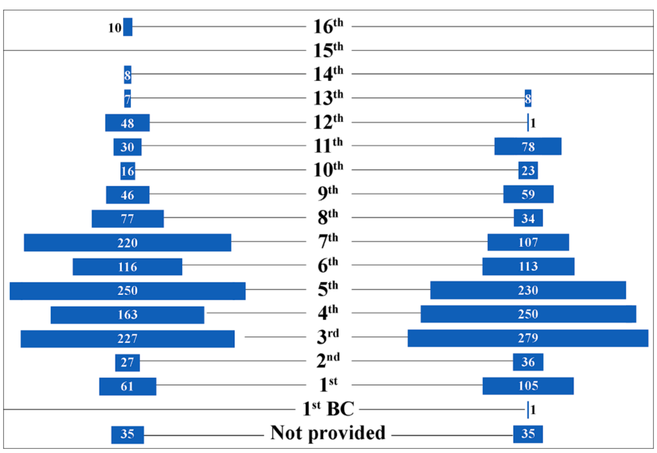


Fig. 2. The chronological distribution. The most recent and oldest dates were used for the left and right diagrams, respectively.

compatibility with one of the two areas was observed, it was indicated as "base glass" or "Egyptian mixed" or "Levantine mixed". In cases where it is impossible to refer to any particular macro-area, such as for Roman Mn-Sb glass, the sample is indicated only as "mixed".

A necessary clarification concerns the treatment of literature data. Unfortunately, the cases in which Sb or Sr and Zr have not been measured are many and add up to instances in which the measurements are partially inaccurate in an obvious way. Undoubtedly the quality of the reconstructions depends on the availability and accuracy of the raw data and these intrinsic deficiencies or weaknesses are detrimental to the research as a whole. An example case concerns the high number of samples for which Sb levels were indicated as "less than 0.06″ or ″less than 0.04″ wt% Sb_2O_3 (~501 and 334 ppm Sb, respectively). These values would not allow assigning the samples with certainty to the Roman Mn group; however, a forcing was necessary to maintain a statistically representative basis on which to reason.

Perhaps it is all too obvious to specify. Still, another limitation of the research is that it is based on a repertoire of materials which describe the state of the art of archaeometric research but do not necessarily represent the most widespread glass types in the various periods considered.

Net of all the issues discussed above, the database totals 170 samples that can be assigned to the *s.s.* groups, 536 to the *total* groups, 164 classified as *similar* and 487 as *mixed*, with percentages that undoubtedly vary from site to site.

3. Glass distribution

3.1. The entire repertoire

The predominance of Egyptian products over those of Levantine provenance is striking clear when the entire database is considered.

The pie chart in Fig. 3A shows that Egyptian products represent 50% (*s.s.* + *total* + *similar*) to 71% (including Egyptians mixed) out of 1357 samples. Based on the same criterion, the Levantine products vary from 17% to 19%, while the remaining 14% includes *mixed* glass.

Looking at the distribution of materials in each of the four countries (Fig. 3B), the trend is comparable even if it differs in relative proportions. For example, the ratio between Levantine and Egyptian products is about 1:3.1 in Croatia, 1:2.5 in Italy, 1:6.9 in Serbia and 1:21.5 in Slovenia.

By normalising the values to the total of the finds analysed for each country (Fig. 3C), the predominance of Egyptian products is even more evident, especially in Slovenia, whose products - dated mainly between the 4^{th} and 7^{th} c. - are almost exclusively Egyptian.

By separating the Italian materials found in northern and southern sites (Fig. 3D), it can be observed that the Egyptian products are predominant with a ratio of 1:2.3 and 1:3.1 in favour of the latter in the north and the south, respectively. Again, the higher ratio observed at the southern sites can be explained based on the chronology of the finds. As a matter of fact, the collections analysed in the south are almost exclusively late antique and early medieval. Conversely, the collections from the northern sites are chronologically well distributed throughout the imperial age to the Middle Ages. The normalised data (Fig. 3E) also highlight how the percentage of mixed materials is high but not preponderant in both the south (13%) and the north (14%).

3.2. Levantine glass

In Fig. 4, the diagrams A-D illustrate how 1^{st}-3^{rd}-c. Roman Mn glass is abundant, 4^{th}-c. Jalame-type is frequent, 6^{th}-7^{th}-c. *Apollonia*-type glass is sporadic and 7^{th}-9^{th}-c. Bet Eli'ezer type glass is extremely rare (as well as of doubtfull assignment). In this regard, however, it must be underlined

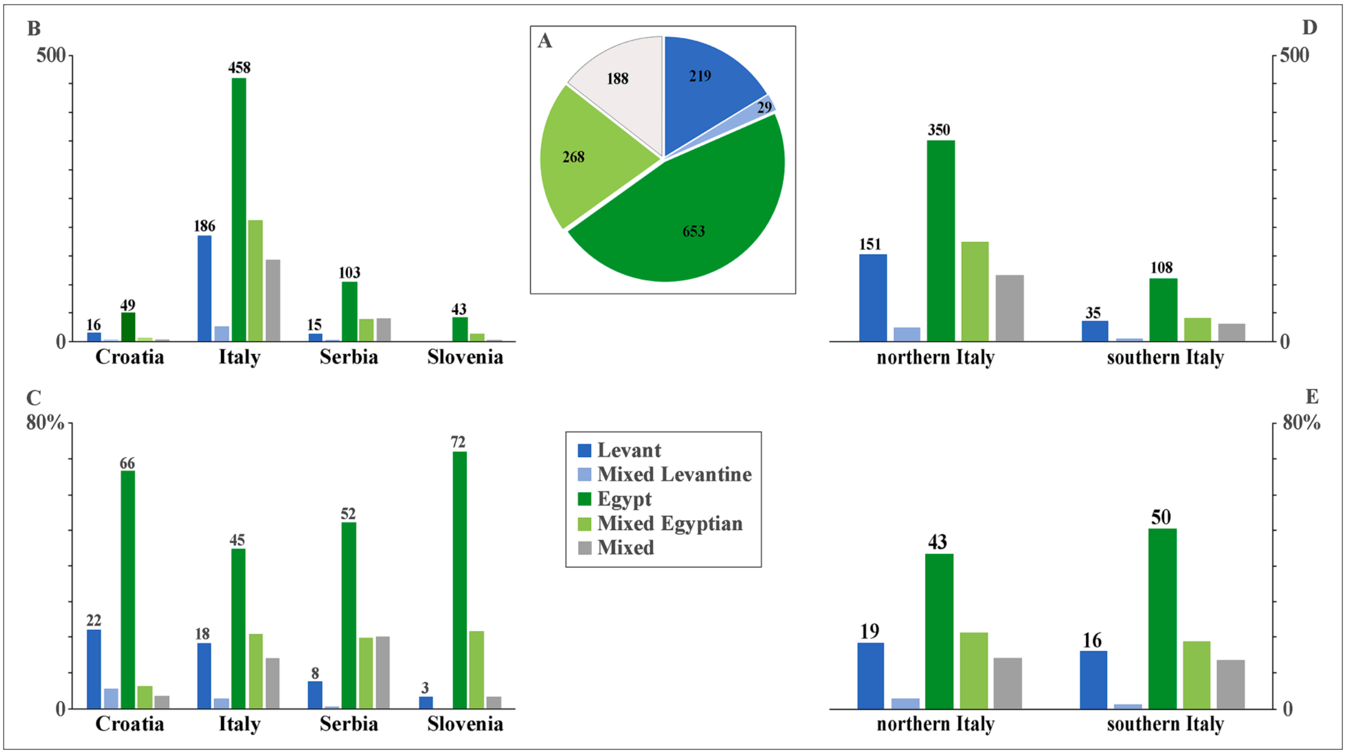


Fig. 3. Glass provenance. Absolute values (A-B, D) and percentages (C, E) summarising the distribution of Levantine and Egyptian products.

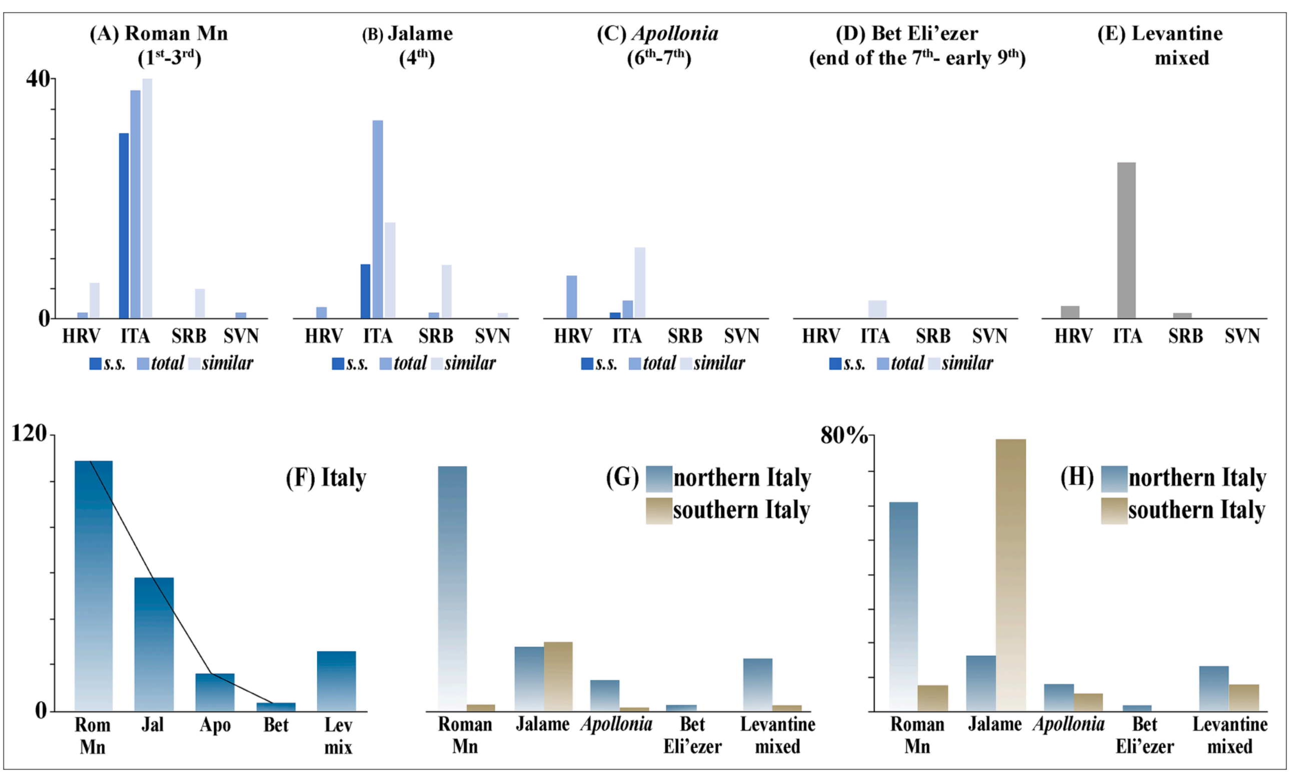


Fig. 4. The distribution of Levantine glass in the considered countries (A-E) and in Italy (F-H). The chronologies indicated under the label of the reference groups are those of the reference group itself. [Abbreviations: HRV = Croatia, ITA = Italy; SRB = Serbia; SVN = Slovenia; RomMn = Roman Mn, Jal = Jalame; Apo = *Apollonia*; Bet = Bet Eli'ezer).

that many specimens assigned to the Roman Mn type could also be classified as mixed Roman Mn-Sb glass because -as anticipated in the previous section- the measurements of the antimony contents still need to be established with certainty.

In this first series of diagrams, it is also helpful to note that glass *s.s.* is always lower than that containing high amounts of colouring agents or recycling traces (*total* and *similar*). This trend is particularly evident both in Italy, where the data are consistent and in other countries, where the occurrences are quantitatively lower. It should also be added that Levantine mixed glass (Fig. 4E) is attested in all periods but frequent only from the 2nd c. onwards.

The diagram in Fig. 4F displays the frequency of Levantine glass in Italy. The descending curve shows how Roman Mn and, to a lesser extent, Jalame-type glass represented highly appreciated products in this country, as opposed to *Apollonia* and Bet Eli'ezer glass types which count sporadic attestations.

In Fig. 4G and H, the totals are divided between northern and southern Italy, firstly using absolute values (G) and then normalising them (H). As noted above, the higher incidence of Jalame-type glass in the south than in the north should reflect the chronology of the contexts analysed in the two territories. It is, in fact, probable, even if not readily ascertainable, that Roman Mn glass was widespread in southern contexts of earlier periods than those investigated up to now.

Fig. 5 has been prepared to better outline the frequency of Levantine glass in the investigated periods and to show how this frequency changes when glass objects are dated within wide chronological ranges. Indeed, several glass samples are dated within narrow (*e.g.*, 1st c. CE) or broad periods (*e.g.*, 1st-7th c.); therefore, frequency count can widely vary depending on which dating is considered. The curve on the left shows the totals achieved when a find dated, for example, between the 1st and 3rd c., is counted according to its earliest date (1st c.). Conversely, the curve on the right shows the totals achieved when the same samples are counted according to the most recent date (3rd c. in the preceding case).

Either way, the curves appear similar, showing a sharp increase in the 3rd c. and a gradual decrease from the 4th c. onwards. Finally, the last Levantine production known to us does not arrive later than the beginning of the 9th c.; therefore, the later samples are either recycled from older materials or belong to a production not yet known.

Indeed, both curves partly reflect the state of the art of the studies. However, there is reason to believe that the general picture is representative since the collapse of Levantine imports in the 8th and 9th c. corresponds to plant ash-based glass increasing competition in the market.

3.3. Egyptian glass

The materials available are relatively numerous for Italy and, to a lesser extent, Serbia, while they are scarcer for Slovenia and Croatia (Fig. 6A). More than three-quarters of the materials from Italy were found in the north, while just under the remaining quarter came from southern sites (Fig. 6B). It should also be noted that among the 916 specimens referable to the Egyptian area, as many as 266 are Egyptian mixed glass (Fig. 6C).

Fig. 7 shows the frequency of the various compositional groups in the four countries. Summing *s.s.*, *total* and *similar* and sorting them in descending order, the following list is obtained: Foy 2.1 (235), HIMTa (151), Foy 3.2 (107), Roman Sb (86), HIMTb (51), Foy 2.1 HFe (13), Egypt 2 (6) and Egypt 1 (1). The *s.s.* specimens are minor compared to *totals* except for the Roman Sb group; moreover, the incidence of samples assigned to the Foy 2.1 HFe, Egypt 2 and Egypt 1 groups is practically negligible.

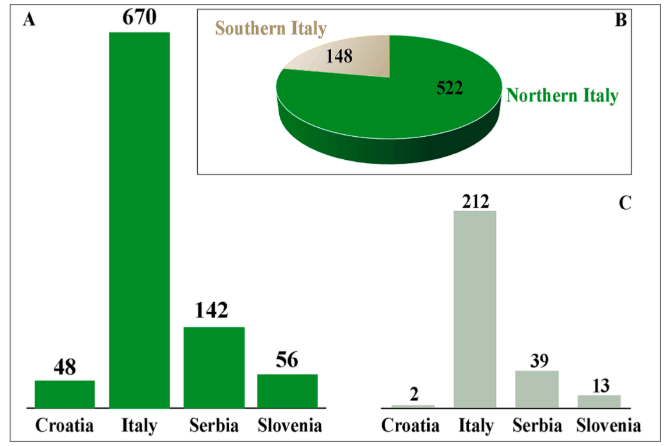


Fig. 6. A) Frequency of Egyptian glass in the four countries. B) How the 670 samples from Italy are distributed between the north and the south. C) Frequency of Egyptian mixed glass.

By reversing the observation point from the group to the country (Fig. 8A-D), the frequency of each group appears variable.

Croatian materials testify to an evident prevalence of the Foy 2.1 series. In Italy, the groups' frequency is rather heterogeneous. Alongside the two most attested groups -Foy 2.1 and HIMTa- Roman Sb, Foy 3.2 and HIMTb glass are relatively well attested. On the other hand, the Foy 2.1 high Fe and the Egypt 1–2 series appear to be minorities. In terms of absolute values, most materials appear to be made up of mixed glass, for which an Egyptian provenance is likely. In the latter case, the most represented groups are the Foy 2.2 and the combination obtained by mixing Foy 3.2 with Roman Sb glass.

The general framework that can be reconstructed for Serbia appears heterogeneous too and, even more interestingly, different from the Italian one, except for the substantial incidence of Foy 2.1. In Serbia, the HIMTa group is scarce, while the Foy 3.2 is even more attested than Egyptian mixed glass. Roman Sb and Foy 2.1 high Fe glass are relatively well established, while HIMTb and the Egypt series are presently absent.

Finally, Slovenia presents a situation similar to that of Serbia, despite the smaller number of samples investigated overall. Foy 2.1 is the one most attested group and is followed by Egyptian mixed glass, Foy 3.2, HIMTa and HIMTb. The other groups have not been found so far.

The differences observed between the Italian and Serbian repertoires appear significant and deserve further study. In Fig. 8E-K, the values obtained for each compositional group are normalised to the total

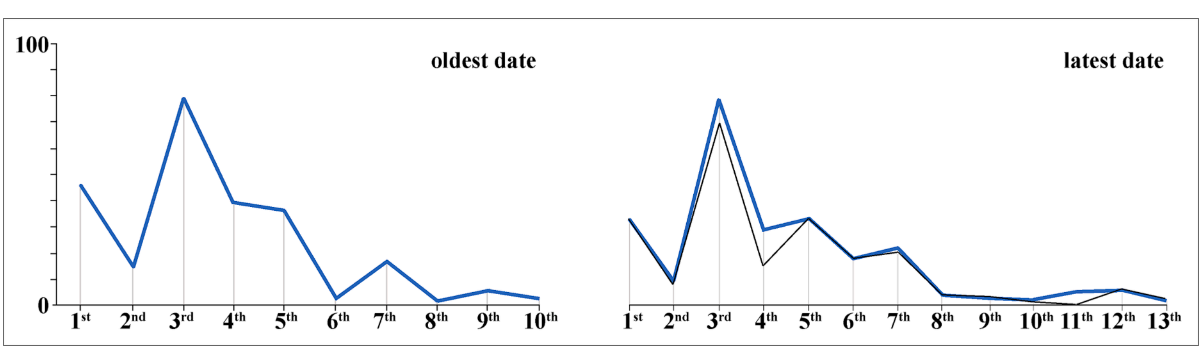


Fig. 5. Diachronic view regarding Levantine imports. The blue line regards the entire database, while the black line concerns the specimens found in Italy. In the left diagram, the black line has not been reported because it coincides with the blue line.

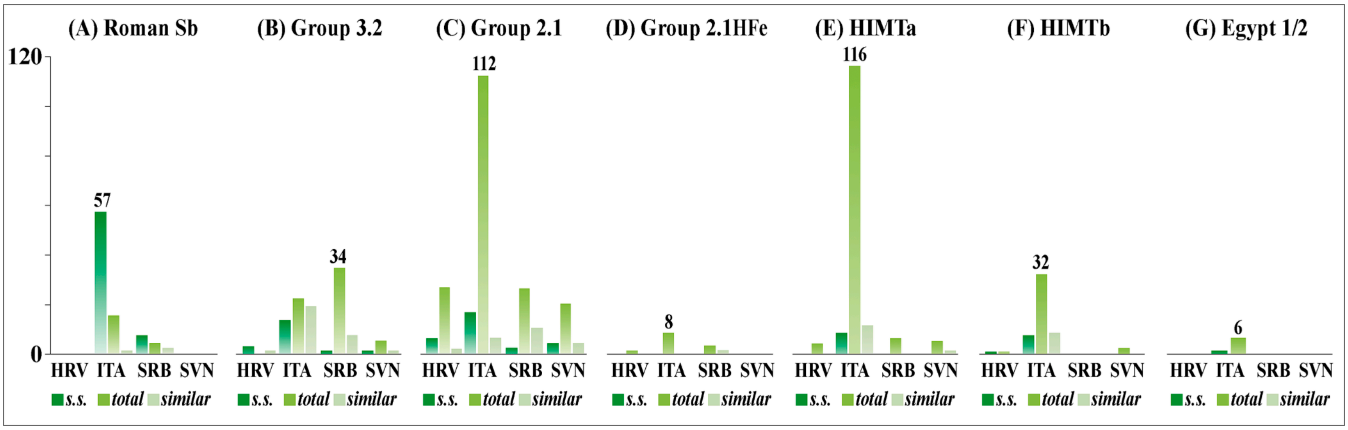


Fig. 7. Egyptian glass. Frequency of each group in each country. [Abbreviations: HRV = Croatia, ITA = Italy; SRB = Serbia; SVN = Slovenia).

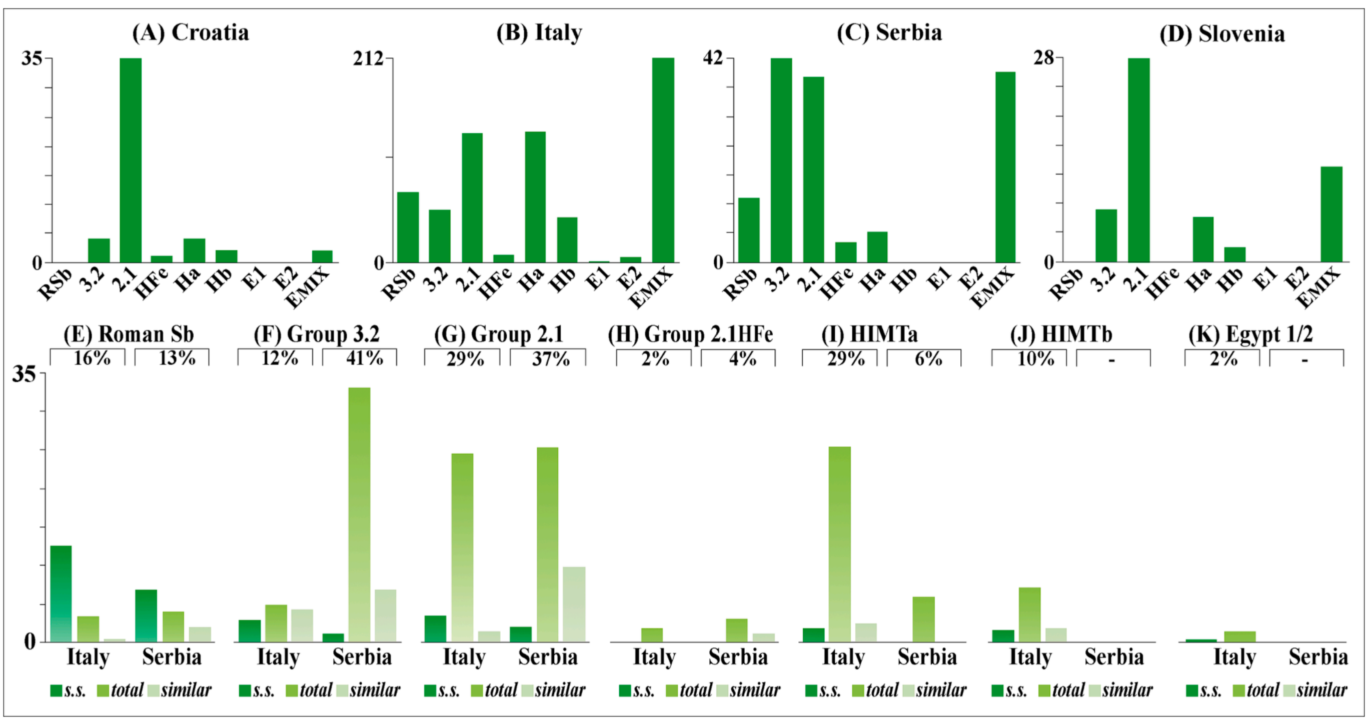


Fig. 8. A-D) The distribution of the compositional groups within each country. E-K) Frequency data normalised to the total occurrences of Egyptian materials in each country.

Egyptian finds of each country in an attempt to decrease the inevitable imbalance due to the higher number of Italian samples (670) than the Serbian (142).

This series of diagrams shows how only Foy 2.1 and Roman Sb glass are testified by comparable percentages in both territories (Fig. 8E and G). In order of occurrences, HIMTa glass represents the second group in Italy, while it is only fourth in Serbia (Fig. 8I). In the latter country, Foy 3.2 glass is the most attested ever (Fig. 8F), followed by Foy 2.1 and Roman Sb glass.

For the purposes of the current research, the distribution of Egyptian products is then investigated within the Italian territory, keeping the discoveries made in the north separate from those in the south. Fig. 9A shows an imbalance between the number of samples investigated in the north (522) and the south (148). However, what is striking is the gap regarding the distribution of the groups Roman Sb (70 specimens in the north and 3 in the south), Foy 3.2 (50 in the north and 4 in the south) and HIMTb (43 in the north and 4 in the south).

The data have been normalised in Fig. 9B to minimise the effect of data bias. The higher frequency of Roman Sb and Foy 3.2 glass in the north than in the south is confirmed, while the gap between the HIMTb percentages decreases.

Foy 2.1 and HIMTa can be safely described as the first two groups in both areas but the relative proportions attest to greater consistency in the south than in the north. On the other hand, the situation in the north seems better distributed among the various groups and even Roman Sb, Foy 3.2 and HIMTb glass play a slightly smaller but still significant role.

In both areas, the percentage of Egyptian mixed glass is particularly high, in contrast to the Foy 2.1 high Fe and the Egypt series glass, which prove to be particularly scarce.

Overall, the most exciting differences concern the Roman Sb and Foy 3.2 groups and it is necessary to understand whether the observed differences are due to the chronology of the investigated contexts -as in the case of Roman Mn- or to a different trade of Egyptian products along the Adriatic Sea. In fact, it cannot be accidental that out of 148 southern

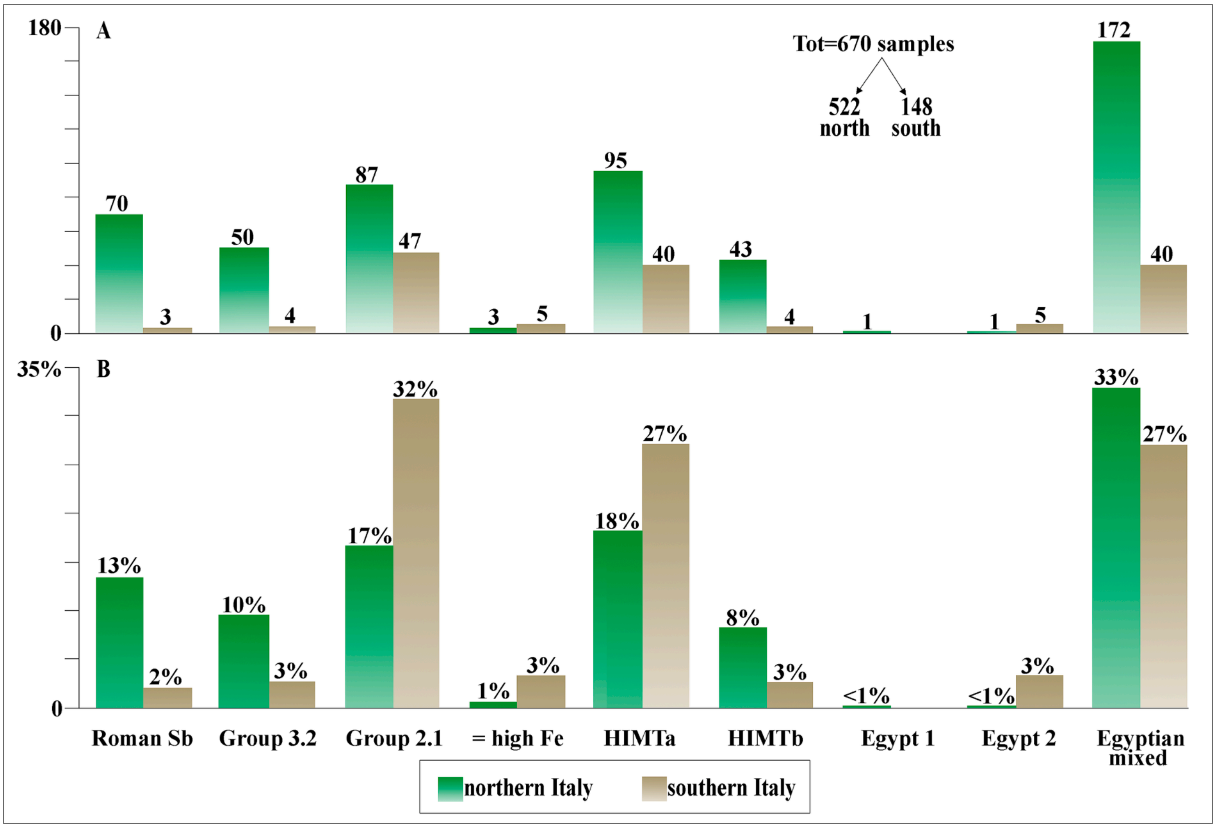


Fig. 9. The distribution of Egptian glass in northern and southern Italy. A) Raw data. B) Normalised data.

specimens referable to the Egyptian area, the groups Roman Sb and Foy 3.2 count only 3 and 4 specimens, respectively.

Fig. 10 allows the diachronic distribution of the various Egyptian groups to be observed. As in Fig. 5, the visualisation is twofold to account for the many specimens dated over two or more centuries. The Roman Sb group is present from the 1st or 2nd c. and peaks in the 3rd c. (75/80% of attestations). However, the luck of this group seems to be short-lived as the samples dated to the following centuries are only 11% (using the oldest dating; Fig. 10A) or 23% (using the latest dating; Fig. 10B). Therefore, the gap previously observed in the distribution of this glass in northern and southern Italy can undoubtedly arise because the contexts analysed in the south do not cover its period of most significant diffusion.

Foy 3.2 glass presents two different trends depending on the reference chronology. Using the oldest dating (Fig. 10C-D), the group appears consistent in the 3rd c. and grows abruptly in the 4th c. After reaching the peak in the 5th, it begins a gradual decline, leading it to be practically irrelevant in the 7th c. Conversely, using the latest dating, the peak is reached in the 4th c. After, there is a sort of stasis until the 8th c., followed by the almost disappearance of this group.

Hence, the poor distribution of this glass in the south cannot be explained by the chronology of the contexts: *Salapia* materials are dated from the 3rd to the 7th c. (Gliozzo et al., 2023a), Faragola from the 3rd to the 9th c. (Gliozzo et al., 2016a), *Herdonia* from the 3rd to the 10th c. (Gliozzo et al., 2016b), San Giusto from the 4th to the 9th c. (Gliozzo et al., 2019a) and *Canusium* from the 4th to the 9th c. (unpublished personal data).

The only context dated outside the period of diffusion of Foy 3.2 glass is that of Siponto (9th-13th c.; Genga et al., 2008), which contributes to the total with only seven specimens.

The HIMTa group does not appear widespread before the 3rd/4th c. and reaches the peak in the 4th/5th c. (Fig. 10E-F). With the 5th/6th c., there is a more or less marked decline but it is only in the 9th c. that HIMTa glass tends to disappear, in conjunction with the diffusion of plant ash-based glass.

Similarly, HIMTb glass appears in the 3rd or 4th c. and after reaching its peak in the 5th c., it drops sharply (Fig. 10G-H). The duration of this glass appears later and shorter than that of HIMTa since the occurrences are pretty rare after the 7th c.; moreover, even in the period of most significant diffusion, it never reaches the quantitative levels of HIMTa.

Foy 2.1 glass appears ubiquitous; however, the quantities are consistent only from the 4th/5th c. (Fig. 10I-J). The samples with the oldest date before the 4th century are only 16, of which 9 are dated between the 1st and 7th c. The apex is reached in the 5th (using the oldest dating) or in the 7th c. (using the latest dating). Therefore, it is likely that an intermediate dating between the 5th and 6th c. represents the most important period for this production, which gradually runs out from the 8th c. The diagram's tails are due to the broad dating (for example, the peak in the 11th c. due to samples dated between the 5th and 11th c.) and recycling in the more recent centuries.

The groups Foy 2.1 high Fe and Egypt 1–2 still need to provide sufficient data to be statistically reliable. However, it is possible to observe a later distribution than the previous groups, which partially overlap.

Finally, it is interesting to observe how in the column of diagrams using the latest dating, the peaks of the first five groups progress from the oldest to the latest.

4. An overview on glass trades in the Adriatic Sea and beyond

The study of an archaeometric database comprising 1357 Italian, Croatian, Slovenian and Serbian samples has provided a diachronic overview of the Adriatic's glass trade (Fig. 11). However, the chronological seriation and the proposed reconstruction of glass trade networks must be taken cautiously since data are still few and sparse.

The framework is represented by the present state of the art and is,

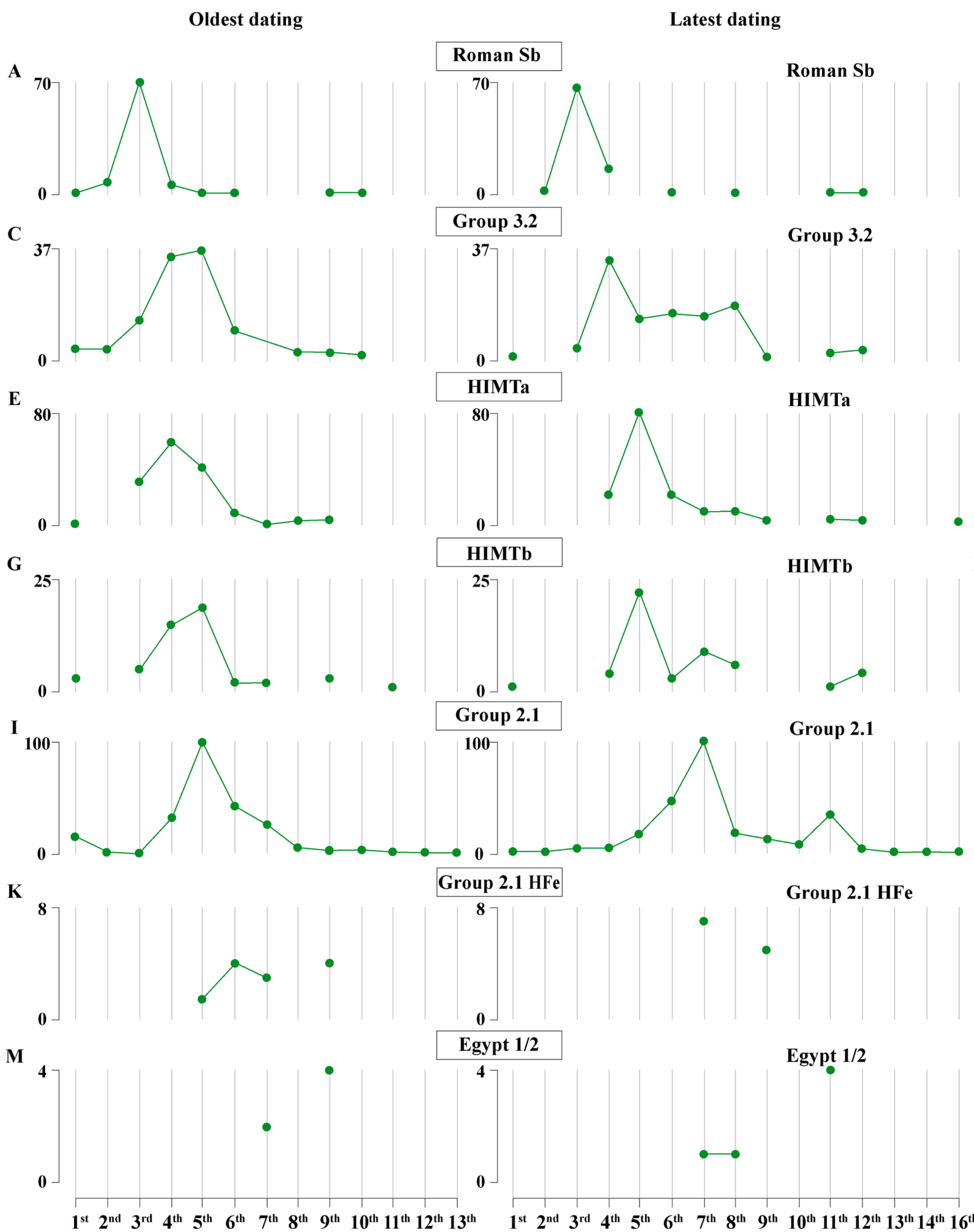


Fig. 10. Diachronic distribution of Egyptian glass.

therefore, sensitive to future modifications. Nevertheless, it is certainly ready to start questioning us about the glass trade in a broader context.

With all the limitations declared from the outset (section 2), the first datum that clearly emerges is the quantitative predominance of Egyptian glass over Levantine glass, starting from Late Antiquity.

The first centuries of the Empire saw the coexistence of Levantine and Egyptian products, respectively testified by the compositional groups Roman Mn and Roman Sb. At the end of the 3rd and the

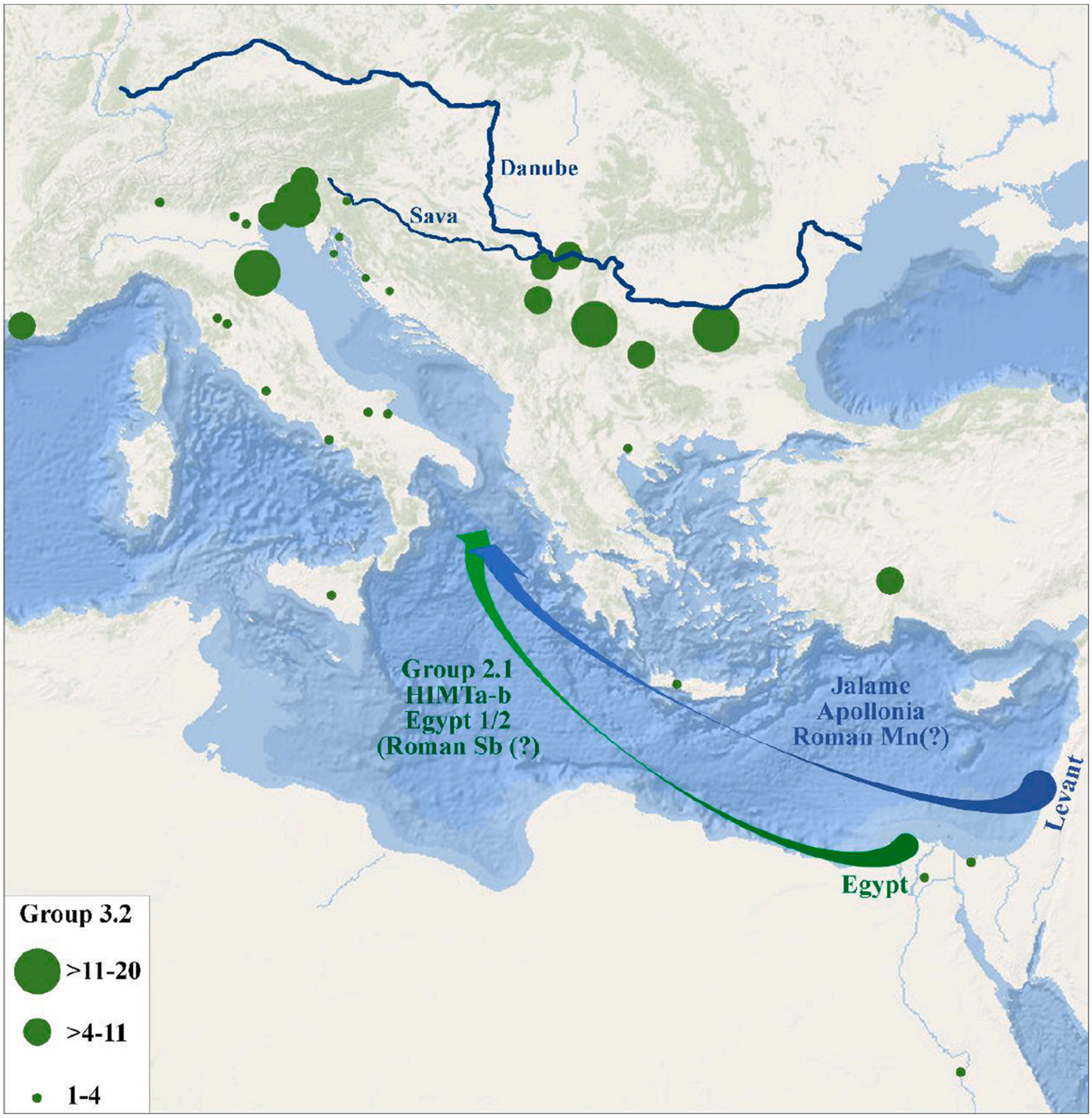


Fig. 11. Glass trade in the Adriatic Sea and beyond. N.B. not all occurrences of Foy 3.2 are reported in this figure.

beginning of the 4th c., the Jalame-type Levantine products gradually gave way to Egyptian products, which, from this moment on, became predominant, at least from a quantitative point of view. In practice, the Mn-rich Foy 3.2 glass gradually replaced Roman Mn glass but only in some places. The territories of southern Italy had minimal access to these products. At the same time, they intensified the import of HIMTa and Foy 2.1 glass, representing the two main groups for at least two to three centuries. On the contrary, the diffusion of Foy 3.2 glass in northern Italy is comparable to that observed in Slovenia and Serbia. The numerous works carried out in this area have highlighted how this compositional group was prevalent even with respect to HIMTa glass which, on the other hand, experienced a widespread diffusion in Italy and the entire Mediterranean basin up to the United Kingdom.

The comparison between southern Italy, northern Italy and Serbia cannot be explained in chronological terms; therefore, a diversification of the glass trade network can be hypothesised. Although the provenance reassessment has yet to be concluded, further data in support of this thesis seems to be offered by the Albanian glass. A preliminary survey carried out on a total of 139 vessels dated between the 1st and 13th c. and found in Butrint (Conte et al., 2014; Schibille, 2011) and Komani (Neri et al., 2019a) or of unknown provenance (Šmit et al., 2013b) returned a total of only eight specimens compatible with the composition of Foy 3.2 glass. Unfortunately, the contexts analysed on the western coast of Greece (*e.g.*, Gitana, Dimokastro and Elea; Oikonomou et al., 2020) date back to an earlier period than this production (overall 4th c. BCE – 1st c. CE) and it is therefore not possible to draw a comparison.

As far as can be observed to date, the diffusion of Foy 3.2 glass neglected the southern Adriatic coast, much of the Italian Tyrrhenian coast and other territories like Spain, where the occurrences are sporadic and never quantitatively relevant. The same situation seems to be observable along the central Macedonian and Thracian coast, where Foy 3.2 glass was absent in Maroneia or minimally present in Thessaloniki (Silvestri et al., 2017).

The most significant concentrations (from 4 to 20 specimens) have been found in Classe (Maltoni et al., 2015; Neri et al., 2016), Aquileia (Gallo et al., 2014; Maltoni et al., 2016; Maltoni and Silvestri, 2018) and Jesolo (Gliozzo et al., 2023b) in northern Italy; Serdica (Cholakova et al., 2016) and Dichin (Rehren and Cholakova, 2010) in Bulgaria; Tonovcov grad in Slovenia (Šmit et al., 2013a); Stojnik castrum (Stojanović et al., 2015), Gradina – Jelica (Balvanović et al., 2018; Balvanović and Šmit, 2020), Viminacium (Balvanović et al., 2022) and Medijana (Stamenković, 2015) in Serbia.

From the general picture obtained to date, it is thus possible to infer that Foy 3.2 glass did not entirely follow the same commercial routes as the Egyptian groups Foy 2.1 and HIMTa-b (present in both northern and southern Italy). Its rarity in the south suggests that the Adriatic route was not the preferential one with respect to the Balkan one, likely traced by the courses of the Danube and the Sava (blue lines in Fig. 11). On the other hand, while a Balkan route would fit well with the abundance of this type of glass in northern Italy and northern Europe, two issues cannot be readily solved. Firstly, several alternatives may be hypothesised in trying to connect Egypt with the Balkans. For examples, the small number of specimens found in the northern Greek coast (Macedonia and Thrace) as opposed to the high number of samples recovered in Bulgaria would seem to indicate a route that reaches from the Aegean -or crossing Turkey?- to the Black Sea. Undoubtedly a very long journey that does not find a simple explanation. This is not the place to address this question but one wonders if it is actually realistic to think that there were no primary productions in Turkey where white sands outcrop, for example, not far from Byzantium. Perhaps, the continuation of the research will shed light on this issue. For the moment, in fact, the provenance reassessment of materials from Turkey and from other countries such as Romania, the rest of Bulgaria and northwestern Europe is not concluded. Moreover, this theory is based on the abundant distribution of Foy 3.2 glass in Serbia, Bulgaria and northern Italy and on its contemporary scarcity in southern Italy, therefore, new discoveries in *Apulia* could modify the picture currently available. The second issue may be provided by the evidence recovered in southern coastal France. For example, the Marseilles findings (Foy et al., 2003) trace a further route which not only does not seem to reach Spain but which could somehow escape the Balkan route model.

Overall, it becomes ever clearer that to clarify old and new doubts - not only for this single case - it will also be mandatory and inevitable to move away from the study of the single type of material and compare the results obtained on glass with that of other materials, not just ceramics.

Resuming with the other groups, there are no reasons to doubt that the Adriatic Sea was the main trade route of Levantine and Egyptian (HIMTa-b, Foy 2.1, Foy 2.1 high Fe and the Egypt series) glass found in Italy. The only remaining doubts concern the ancient groups, Roman Mn and Roman Sb. The sporadic occurrence of this glass in southern Italy is undoubtedly due to a lack of ancient contexts in the archaeometric literature but other explanations could arise from the deepening of the investigations.

In addition to the results presented above, the database study also brought out the need to extend the studies to numerous territories, particularly to the eastern Adriatic coast. Secondly, it highlighted the need for more typological information regarding the investigated vessels. This topic has not been addressed here due to space constraints; however, it must be noted that the cases in which the provenance can be associated with a specific morphological type are not the majority and this approach severely limits future possibilities to achieve significant historical reconstructions.

CRediT authorship contribution statement

Elisabetta Gliozzo: Conceptualization, Investigation, Methodology, Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Margherita Ferri:** Writing – review & editing. **Francesca Giannetti:** Writing – review & editing. **Maria Turchiano:** 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.

Data availability

This is a review of published data

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2023.104180.

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SUPPLEMENTARY MATERIALS

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Table S1. The reference and compositional groups used for comparison.

Group	Reference
Apollonia	Freestone et al. 2000
Jalame	Brill 1988
Bet Eli'ezer	Freestone 2000
Roman Mn	Personal database
al-Raqqa type 3	Henderson 1999
Group E	Mirti et al. 1993
HIMT	Freestone 1994
Foy Série 1 and 2.1	Foy et al. 2003; Schibille 2022
Foy Série 3.2	Foy et al. 2003; Cholakova and Rehren 2018
HIMT1-HIMT2	Foster and Jackson 2009
HIT	Rehren and Cholakova 2010, Smith et al. 2016, Rosenow and Rehren 2018
weak and strong HIMT	Rosenow and Rehren 2014
HIMTa-b and HLIMT	Ceglia et al. 2015
Egypt 1A, 1B, 1C, 2 (low/high Na_2O)	Schibille et al. 2019
Roman Sb	Personal database

Table S2. The average composition of the Levantine reference groups.

Group	Roman Mn		*Apollonia*		Jalame		Bet eli'ezer	
Measurements n=	45		48		53		33	
Chronology	1st-4th		6th-7th		4th		6th-7th	
	av.	sd.	av.	sd.	av.	sd.	av.	sd.
SiO_2 (av.)	69.83	2.32	71.38	1.6	69.74	1.6	75.05	1.5
TiO_2 (av.)	0.11	0.16	0.11	0.1	0.09	-	0.11	-
Al_2O_3_av	2.47	0.41	3.28	0.5	2.74	0.2	3.33	0.3
FeO_av	0.50	0.30	0.49	0.3	0.41	0.2	0.53	0.2
MnO (av.)	0.83	0.55	0.02	-	0.63	0.9	0.03	-
MgO (av.)	0.65	0.20	0.66	0.2	0.58	0.1	0.62	0.1
CaO (av.)	7.05	1.21	8.19	1.0	8.69	0.6	7.06	0.7
Na_2O (av.)	15.98	1.48	14.21	1.4	15.74	0.9	12.06	1.3
K_2O (av.)	0.58	0.20	0.61	0.2	0.78	0.1	0.46	0.1
P_2O_5 (av.)	0.12	0.07	0.05	-	0.14	-	0.09	-
SO_3 (av.)	0.31	0.21	0.16	0.1	-	-	0.15	0.1
Cl (av.)	1.12	0.24	0.81	0.1	-	-	0.64	0.1

Table S3. The average composition of the Egyptian HIMT compositional groups.

Group	HIMT		Group 1		HIMT1		HIMTa		Strong HIMT		HIT	
Measurements n=	3		43		123		13		28		15	
Chronology	4th-6th		5th-8th		4th-5th		5th-7th		2nd-7th		4th-7th	
	av.	sd.	av.	sd.	av.	sd.	av.	sd.	av.	sd.	av.	sd.
SiO_2 (av.)	64.86	1.1	64.49	1.4	67.34	1.7	66.22	1.5	64.76	1.6	68.16	1.4
TiO_2 (av.)	0.56	0.1	0.49	0.1	0.33	0.1	0.47	0.2	0.50	0.1	0.57	0.2
Al_2O_3_av	3.18	0.3	2.88	0.3	2.49	0.3	2.95	0.3	2.70	0.2	3.09	0.3
FeO_av	2.40	0.7	2.05	0.8	1.22	0.2	1.56	0.3	1.84	0.7	1.42	0.1
MnO (av.)	2.25	0.6	2.02	0.4	1.71	0.3	2.02	0.5	2.01	0.4	0.07	0.1
MgO (av.)	1.21	0.1	1.23	0.2	0.98	0.2	1.06	0.2	1.03	0.1	1.16	0.1
CaO (av.)	5.63	0.8	6.22	0.9	6.08	0.6	5.95	1.0	5.70	0.5	5.36	0.5
Na_2O (av.)	17.72	0.7	19.12	1.4	19.11	1.1	18.32	1.1	18.15	1.1	18.28	0.8
K_2O (av.)	0.45	-	0.41	0.1	0.50	0.1	0.44	0.1	0.42	0.1	0.42	0.1
P_2O_5 (av.)	0.10	-	0.11	-	0.05	-	0.06	-	0.06	-	0.04	-
SO_3 (av.)	0.21	0.1	-	-	-	-	0.25	0.1	0.25	0.1	0.26	0.1
Cl (av.)	0.99	0.1	-	-	-	-	1.00	0.1	1.00	0.1	1.04	0.1

Table S4. The average composition of the Egyptian Foy Série 2.1compositional groups.

Group	Group 2.1*		Group 2.1 (±2sd)**		Weak HIMT		HLIMT	
Measurements n=	51		157/180		29		28	
Chronology	5th-9th		5th-7th		1st-7th		5th-7th	
	av.	sd.	av.	sd.	av.	sd.	av.	sd.
SiO_2 (av.)	64.42	1.1	65.7	1.7	66.11	2.1	65.65	1.28
TiO_2 (av.)	0.16	-	0.15	0.02	0.15	-	0.15	0.02
Al_2O_3_av	2.54	0.2	2.53	0.23	2.32	0.3	2.55	0.18
FeO_av	1.22	0.6	1.04	0.5	0.83	0.2	0.85	0.12
MnO (av.)	1.60	0.4	1.41	0.44	1.05	0.6	1.43	0.29
MgO (av.)	1.23	0.1	1.12	0.25	0.93	0.2	1.05	0.13
CaO (av.)	7.78	0.7	8.12	0.92	7.12	1.2	8.14	0.67
Na_2O (av.)	18.50	1.2	17.7	1.3	17.88	0.8	18.37	1.40
K_2O (av.)	0.79	0.1	0.75	0.19	0.54	0.1	0.69	0.14
P_2O_5 (av.)	0.18	-	0.16	0.10	0.08	-	0.14	0.05
SO_3 (av.)	-	-	-	-	0.30	0.1	0.36	0.08
Cl (av.)	-	-	0.83	0.11	1.01	0.1	0.85	0.08

* Foy et al. (2003); ** Schibille (2022).

Table S5. The average composition of the Egyptian Foy Série 2.1compositional groups.

Group	Group 3.2*		Group 3.2 (±2sd)**		Group 3.2***		HIMT2	
Measurements n=	19		64/99		42		221	
Chronology	1st-6th		4th-5th		4th-6th		3rd-5th	
	av.	sd.	av.	sd.	av.	sd.	av.	sd.
SiO_2 (av.)	68.36	1.7	68.1	1.7	68.15	1.87	68.77	1.6
TiO_2 (av.)	0.09	-	0.10	0.03	0.09	0.02	0.12	-
Al_2O_3_av	1.93	0.2	1.94	0.19	1.93	0.21	2.25	0.2
FeO_av	0.64	0.1	0.61	0.24	0.54	0.12	0.65	0.1
MnO (av.)	0.91	0.4	0.83	0.27	0.84	0.20	0.98	0.2
MgO (av.)	0.66	0.2	0.64	0.21	0.56	0.15	0.76	0.1
CaO (av.)	6.88	0.8	6.61	0.86	6.59	0.91	6.00	0.6
Na_2O (av.)	18.63	1.0	19.0	1.1	19.04	1.01	19.65	1.0
K_2O (av.)	0.43	0.1	0.47	0.16	0.42	0.07	0.58	0.1
P_2O_5 (av.)	0.08	-	0.05	0.03	0.04	0.02	0.05	-
SO_3 (av.)	-	-	-	-	0.21	0.09	-	-
Cl (av.)	-	-	1.23	0.24	1.16	0.21	-	-

* Foy et al. (2003); ** Schibille (2022); *** Cholakova and Rehren (2018) including both the main and the high-Sr groups.

Table S6. The average composition of the Egyptian series.

Group	1A		1B		1C		2 (high Na_2O)		2 (low Na_2O)	
Measurements n=	32		45		6		12		24	
Chronology	8^{th}-10^{th}		8^{th}		8^{th}-9^{th}		8^{th}-9^{th}		9^{nd}-12^{th}	
	av.	sd.	av.	sd.	av.	sd.	av.	sd.	av.	sd.
SiO_2 (av.)	72.44	1.69	71.60	1.16	70.31	1.00	69.75	1.92	70.09	1.36
TiO_2 (av.)	0.28	0.05	0.50	0.06	0.34	0.03	0.20	0.03	0.27	0.03
Al_2O_3_av	3.75	0.26	4.38	0.21	3.14	0.25	2.00	0.31	2.52	0.20
FeO_av	1.02	0.13	1.63	0.32	1.14	0.10	0.75	0.28	1.06	0.29
MnO (av.)	0.03	0.01	0.04	-	0.44	0.47	0.05	0.08	0.44	0.47
MgO (av.)	0.64	0.07	0.87	0.08	0.81	0.12	0.47	0.09	0.70	0.15
CaO (av.)	3.08	0.37	3.07	0.17	5.64	1.16	8.51	1.32	9.57	0.54
Na_2O (av.)	16.61	1.15	16.02	1.04	15.89	0.44	16.49	1.04	13.39	0.56
K_2O (av.)	0.59	0.14	0.50	0.07	00.73	0.09	0.33	0.09	0.51	0.25
P_2O_5 (av.)	0.09	0.05	0.08	0.03	0.16	0.07	0.10	0.05	0.11	0.05
SO_3 (av.)	-	-								
Cl (av.)	1.02	0.09	0.98	0.08	0.96	0.08	1.08	0.13	1.04	0.10