PGAA ANALYSES ON ROMAN GLASS FINDS FROM *TOMIS*

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Abstract. This paper reports the *Prompt Gamma Activation Analysis* (PGAA) measurements on twenty glass fragments discovered at *Tomis*, Constanţa, Romania, tentatively dated to the Early Roman period. Most of the analyzed glass samples are colorless, featuring different compositions: antimony decolorized, manganese decolorized or resulting from recycling both types of decolorized glass.

Key words: *Tomis*, PGAA, Roman glass.

1. INTRODUCTION

The use of scientific methods in art and archaeology led to the advent of a new field of multidisciplinary research: archaeometry. The actors carrying such scientific studies – physicists, chemists, geologists, biologists, on one side, and archaeologists, curators, art historians, and restorers, on the other side – must play their part in synergy with the other participants. A clear communication between the involved parties in such enterprises is essential for establishing successful and long-term projects, meaningful from scientific point of view and useful for the entire society.

For the wide audience, the most famous archaeometric application is ^{14}C dating of ancient artefacts using Accelerator Mass Spectroscopy (AMS) technique [1, 2]. Less known for the laymen is that archaeometric analyses can be useful for the determination of the raw materials from which ancient finds were made. By studying the chemical composition and/or the inner structure of artefacts, the analyses might help understanding the manufacturing techniques; in particular cases, they can be used to trace back the provenance of particular archaeological items or they might serve to identify sources of geological materials – *e.g.* obsidian, lithic materials, gemstones, and even metallic ores.

A very insightful application of archaeometry is testing the authenticity of objects proposed for acquisition to museums or private collectors. On a more practical level, this kind of research provides an invaluable help to prepare and carry out restoration/conservation procedures.

Physical and chemical methods applied to the study of art and archaeological objects can lead to spectacular results (sometimes only qualitative, but in most cases truly quantitative) that help archaeologists understand the way our ancestors lived – resources, skills or trade connections between geographically remote communities.

During the last three decades, remarkable advances in the field of archaeometry took place in our country – practically, until recently, *a terra incognita* for this kind of studies. Our late colleague, Bogdan Constantinescu, was a major player in this process, publishing a large number of studies and collaborating with many historians and archaeologists from Romania and abroad. Probably his most outstanding scientific contribution was to the process of authentication of the gold Dacian bracelets recovered by the authorities from the black market [3]. He incessantly and enthusiastically worked to characterize and understand an impressive number of artefacts unearthed on the Romanian territory, by analyzing objects discovered in many archaeological sites or from the collections or deposits of various museums. We will recall here only some of his last papers – as our colleague constantly (*nomen est omen!*) worked until the very last moments of his life, with joy and childish enthusiasm, to study different kind of cultural heritage artefacts: icons, paintings, coins, gemstones, tools and adornments [4–10].

1.1. ARCHAEOLOGICAL BACKGROUND

Tomis was founded during the 6th century BC as a colony of the Greek city *Miletus*. In 86 AD, during the reign of the emperor Domitian, *Tomis* became the capital of the Roman province *Moesia Inferior*, as all the other Greek colonies from the western coast of the Black Sea – *Pontus Euxinus* for the Romans.

Generous amounts of money were invested in the development of *Tomis* as this city was the seat of the governor of *Moesia Inferior* province; a large number of buildings and monuments typical for the Roman world were constructed here. *Tomis* and the nearby cities – *Histria* and *Callatis* – became part of the economic system organized and controlled by the Romans.

Under the emperor Trajan the entire city was rebuilt; later on it received the status of *civitas libera* that allowed its further development; under the emperor Antoninus Pius, *Tomis* was called "*the most exquisite metropolis of the left Pontus*".

During the 2nd–3rd centuries AD many great edifices and monuments were built at *Tomis* – an amphitheater, a stadium, the seat of the merchants from Alexandria, the so-called "great building with mosaic", the baths (*thermae*), etc.

During the 3rd century AD, *Tomis* became the capital of *Scythia Minor* province. The city continued its existence as an important regional center until the end of the 7th century AD, when the city fell under the Migratory attacks [11].

1.2. THE RATIONALE BEHIND THIS ARCHAEOMETRIC STUDY

In the Mediterranean area, during the Roman period, glass had a relatively constant chemical composition [12]. However, according to some slight differences in the raw materials or working procedures, several compositional groups emerged in the archaeometric literature [13, 14].

The centralized model of Roman glass manufacture assumes the existence of two kinds of workshops: primary and secondary. Raw glass was fused by mixing calcareous sands taken from certain Mediterranean beaches with the mineral flux natron. This first manufacturing step occurred in a small number of large-scale primary workshops located in Egypt and on the Levantine coast of the Mediterranean Sea. The secondary glass workshops were spread all over the Empire and they produced various finite items (vessels, window panes, jewels) using as raw materials mainly glass chunks imported from the remote primary workshops [12–14].

Being a precious commodity, glass recycling was a current practice; thus, broken glass pieces were sometimes melted and mixed in the secondary workshops [12–14].

During the Early Roman period, colorless glass was particularly appreciated. This special type of glass was produced by adding small amounts of selected minerals – namely, manganese or antimony compounds – that removed the green blue, yellow or green hues typical for the naturally colored glass [15].

Archaeological glass finds dated to the Roman period and excavated on Romania's territory were published in several papers/books [16–20].

On the other hand, the number of archaeometric studies on Roman glass finds discovered in Romanian archaeological sites is rather limited [21–24].

By reporting the *Prompt Gamma Activation Analysis* (PGAA) data on several glass fragments discovered at *Tomis*, nowadays Constanţa, this paper tries to provide some information in a field where knowledge is quite scant compared to other regions of the former Roman Empire, adding some brush strokes to the complex picture of the economic activities (crafts and trade) taking place in this important city of the Empire, well connected *via Pontus Euxinus* to the rest of the Roman world.

2. MATERIALS AND METHODS

2.1. MATERIALS

The twenty glass fragments reported in this paper were discovered by the archaeologists from *Muzeul de Istorie Naţională şi Arheologie*, *Constanţa* (MINAC)

in excavations performed in the perimeter of the ancient city – inhabited areas and necropolises [25–27].

During the 1950s and 1960s of the past century, numerous buildings were erected in Constanţa; these extensive construction works involved some rescue excavations in the historical regions of the city, including the peninsular and the extra-peninsular areas.

The twenty vessel fragments studied in this research were kept in the deposits of MINAC. Unfortunately, the precise context of their discovery was lost – therefore these finds are known as *passim*.

A quick study of their shape led to the attribution of most of them to the 2^{nd}–3^{rd} centuries AD.

The majority of the glass fragments are colorless (17 out of 20); fragment N2 has a peculiar aqua blue color and sample N25 feature a pale green hue. A single fragment (N4) has a dark green color; based on its overall characteristics, it was dated to the 4^{th} century AD.

2.2. METHODS

PGAA measurements performed at *Budapest Neutron Centre* (BNC) determined the bulk elemental composition of the *Tomis* glass finds. The principles of the method are described in [28–29]. More details on the PGAA facility from BNC are given in [30].

PGAA provides the bulk average composition of the analyzed object in a completely non-destructive manner. No sample preparation was needed and the samples were measured as they were provided by the archaeologists.

At BNC, this method was previously applied to compositionally characterize ancient glass finds [31–33]. The accuracy of PGAA method has been assessed by measuring a series of certified reference materials – see [32–33].

The quantitative PGAA analysis is based on k_0 principle and it was performed using a PGAA library developed at BNC [29]. The most important source of uncertainty is related to the peak area determination, *i.e.* the counting statistics.

In all samples, the following chemical elements were quantitatively determined: H, B, Na, Al, Cl, Si, Ti, K, Ca, Mn, Fe, Sm and Gd. On the other hand, Mg, S, Co, and Sb were only reported if they were present in the analyzed object in amounts higher than the detection limits of the experimental setup. The results were normalized to 100 wt%.

The PGAA results expressed in wt%, as well as the detection limits, are provided in Table 1 – to visualize this table, the reader is referred to the on-line version of this article. All the detected elements were quantified as oxides, except for Cl that was considered in elemental form. As H, B, Sm and Gd were not taken into account in the following discussion, and for space limitations, these data were not given in Table 1.

Some comparison terms, based on the compilation of a large number of analytical data from the archaeometric literature, are also given in Table 1 [13, 15, 34–38].

3. RESULTS AND DISCUSSIONS

All analyzed samples are soda-lime-silica glasses, with the following mean values of the main oxides: (18.42 ± 1.76) wt% Na_2O, (6.53 ± 0.92) wt% CaO, and (68.19 ± 1.66) wt% SiO_2. Potash (K_2O) and magnesia (MgO) concentrations in almost all samples are ≤ 1.5 wt%, indicating the use of natron as the mineral flux, a technology typical for the Roman period [12–14, 39]. It is worth mentioning that potash was quantitatively determined in all samples, while magnesia was in most cases under the detection limits of PGAA, estimated to be ~ 1.0 wt% MgO. Magnesia was determined in amounts higher than 1.5 wt% in just two samples: N2 and N14.

According to their relatively low manganese content (~ 620 ppm MnO on average) and relatively high antimony content (~ 9100 ppm Sb_2O_3), five colorless fragments, namely N6, N9, N13, N14 and N23 were assigned to the Sb-decolorized glass group [15, 34].

During the Roman period, Sb-decolorized glass was one of the most appreciated products of the Egyptian primary workshops [15, 34].

Another group of five colorless samples, namely N12, N22, N25, N34, and N40 were attributed to the Mn-decolorized glass group, according to their relatively high MnO content (~1.93 wt% MnO) and the absence of antimony – at least taking into account the detection limits of the PGAA setup (~ 1000 ppm Sb_2O_3).

During the Early Roman period, Mn-decolorized glass was manufactured mostly in the Levantine workshops, while during the Late Roman period the manufacture of this type of glass was also made in Egyptian primary workshops [15].

Samples N22 and N25 contain particularly high amounts of soda (19.17 wt% and 20.30 wt% Na_2O), respectively, pointing towards an Egyptian origin, while the other three samples of this group, N12, N34 and N40 contain less soda (14.86 wt % 14.83 wt% and 16.31 wt% Na_2O, respectively), suggesting their production in Levantine workshops. Lacking any chronological or typological detail on these samples, we cannot go any further with speculations on this issue.

Sample N25 is also remarkable due to its pale green color – indicating that the decolorizing process was not effective in this case. Possibly this object was produced by recycling – but considering only the PGAA data reported here, we cannot bring further arguments to this hypothesis.

Cobalt was found in the composition of a Mn-decolorized sample – namely N34 – that contains 268 ppm CoO. The presence of these minute amounts of a chromophoric element in the composition of a colorless fragment is suggestive for recycling, the batch including small chunks of blue glass.

Based on the copious amount of data published in the literature, Mn-decolorized glass was especially abundant during the Late Roman period, while Sb-decolorized glass was frequently encountered during the Imperial period, until the 3rd century AD [15].

According to their content of antimony (~ 5600 ppm Sb_2O_3 on average) and manganese (~ 3200 ppm MnO on average), seven samples from *Tomis*, namely N3, N17, N24, N37, R17, R37, R45 — fall in the category of Sb-Mn colorless glass as defined in [15].

The simultaneous presence of both decolorizers employed during the Roman times – antimony and manganese – in these samples, suggest that these glass fragments were manufactured by recycling, *i.e.* by melting cullet originating from both types of colorless glass, namely Mn-decolorized glass and Sb-decolorized glass. The glass waste was carefully selected, paying attention to the color (in this particular case, lack of color) criteria.

Considering the fragility of several fragments from this group that feature very thin walls, we can speculate that the secondary workshops that produced these containers were located in *Tomis.*

There are solid archaeological evidences that several secondary glass workshops were active in *Tomis* during the Early Roman period [18, 40 and references therein]; most likely, glass of different types, originating from various primary workshops – Levantine and Egyptians – was shaped here into various finite products; simultaneously, the raw materials also consisted of chunks and bits of broken glass vessels or window panes.

We can speculate that the fragments of Sb-decolorized and Mn-decolorized vessels were made from fresh glass chunks, probably imported *via* the Black Sea and that no recycling whatsoever was involved in their making (except for sample N34, bearing clear signs of recycling). On the other hand, the Sb-Mn colorless fragments were definitely the products of some secondary workshops – most likely local ones, hypothesis supported by archaeological arguments – as the remains of several such workshops were unearthed at *Tomis* [18, 40 and references therein].

The division of the colorless glass fragments into the three groups is well illustrated by the graph shown in Fig. 1.

Sample N4, due to its high content of iron (1.64 wt% Fe_2O_3), manganese (1.61 wt% MnO) and titanium (0.21 wt% TiO_2) can be attributed to the HIMT (High Iron Titanium Manganese) group [14], the equivalent of *Groupe* 1 of Foy [13]. This is a chemical group of Late Roman glass of Egyptian origin that appeared during the 4th century AD [13–14].

At a first glance, the aqua blue sample N2 has an appearance typical for Roman Imperial glass or Levantine glass. However, its overall chemical pattern does not allow its attribution to any of these chemical groups – see, for example the comparison with the Roman Naturally Colored Blue Green Yellow 2 (RNCBGY2) group as defined in [35]. Against this idea are its high soda content (18.34 wt% Na_2O), relatively higher than the average value of this component in the Imperial

Roman glass (~16.1 wt% Na_2O), as well as its relatively high magnesia content (1.86 wt% MgO), surpassing the 1.5 wt% limit indicating the use of natron. However, its most interesting feature is the very low manganese content (400 ppm MnO). Such a high soda content points towards an Egyptian origin of this glass fragment, while the slightly high magnesia content is a potential indicator of recycling. An alternative explanation would be that this fragment actually dates from the Late Roman period and thus it could be assigned to HIT (High Iron Titanium) chemical group introduced in the archaeometric literature by Cholakova and Rehren by analyzing Roman glass finds from Dichin, Bulgaria from the 5th century AD [36]. However, the lime, alumina, titanium and iron contents of sample N2 are not similar to the ones from Dichin (for example, higher lime and lower alumina in this *Tomis* sample) – and these are precisely the chemical elements/ oxides characteristic of glass-making sands. However, in the literature there are examples of HIT glasses with slightly different compositional patterns and colors – typical Egyptian glass products, but with an extremely low content of manganese [37] – see the comparison terms provided in Table 1.

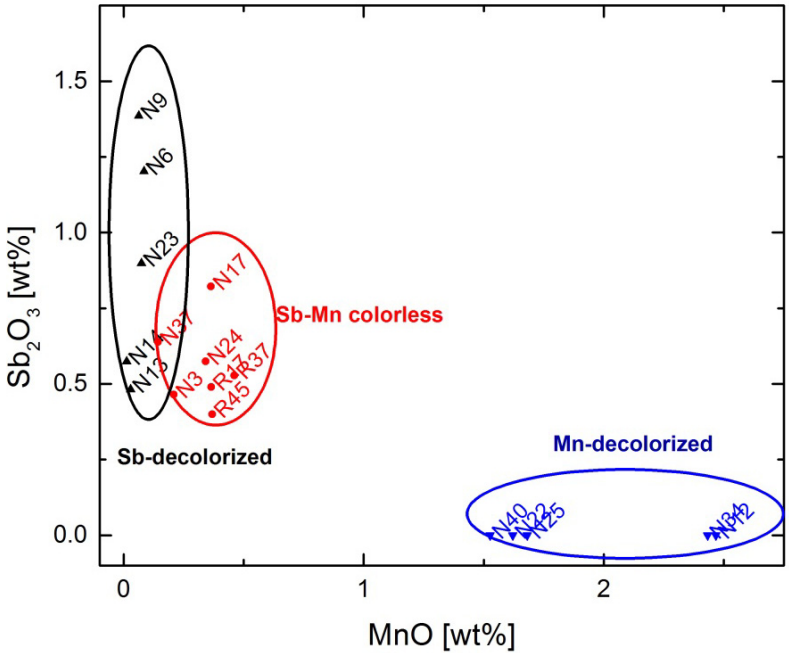

Fig. 1 – Antimony oxide *versus* manganese oxide content for all the colorless *Tomis* glass samples.

Nevertheless, the attribution of this sample to any well-known glass chemical group is complicated by the lack of information about the archaeological context; also considering its high degree of fragmentation, no chronological or typological characterization was possible.

The sample N1 could not be assigned to any of the colorless glass groups, despite its obvious lack of color. In particular, we tried to include this sample in the Sb-Mn colorless glass group, but taking into account the available data, this was impossible, as its antimony content is lower than the PGAA detection limits, estimated to be 1000 ppm Sb_2O_3. The composition of this fragment fits quite well with the one of typical Imperial Roman glass, also known as RNCBGY2 [35]. Its lack of color might be explained through the comparable content of iron and manganese oxides (0.28 wt% Fe_2O_3 and 0.32 wt% MnO, respectively).

It is worth mentioning that several Roman vitreous samples from *Tomis* were previously analyzed and published in [21, 24]; Sb-Mn colorless and HIMT glasses were encountered in those compositional data.

The fact that glass items of both Egyptian and Levantine origins were discovered in this sample set is an archaeometric indicator for the connections of *Tomis*, an important port from the Black Sea coast, with the rest of the Roman world, demonstrating its inclusion in the commercial networks of those times.

On the other hand, the recycled glass fragments – the Sb-Mn colorless samples and the colorless item containing minute amounts of the chromophoric element cobalt – bring archaeometric arguments to the hypothesis that glass was worked in *Tomis* during the Roman period.

4. CONCLUSIONS

The chemical composition of twenty glass vessel fragments discovered in rescue excavation at *Tomis*, nowadays Constanţa, Romania was determined using PGAA technique at BNC. According to their composition, the colorless glass fragments were attributed to different chemical groups from the archaeometric literature: Sb-decolorized, Mn-decolorized, and Sb-Mn colorless/recycled. Three outliers (HIMT, HIT and RNCBGY2) were encountered among the studied glass finds.

The chemical data provided hints about the raw materials (*e.g.* the use of various decolorizers) and working techniques (*e.g.* recycling – the Sb-Mn colorless glass and the colorless sample containing cobalt above the detection limits), and shed some light on the glass making activities in an important city from the Western coast of the Black Sea during the Early Roman period. This study brought archaeometric support to the idea of local glass working in *Tomis* – evidenced by the copious presence in this sample set of recycled Sb-Mn colorless fragments.

This research is a small step forward in a more ambitious project targeting the thorough characterization of vitreous finds discovered in various archaeological sites from the Black Sea coast, expected to generate new data about a subject occasionally tackled until present. However, to properly accomplish such an ambitious task, there is an obvious need for the judicious selection of the artefacts subjected to chemical analyses, properly characterized from archaeological point of

view, as this study demonstrated that the chronological and typological details are crucial for the correct archaeometric characterization of the archaeological finds.

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Table 1

PGAA results on *Tomis* glass samples - all concentrations expressed in wt%, empty cells mean below the detection limits

Sample ID	**Color**	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**
Detection limit [wt%]		***0.10***	***0.05***	***0.50***	***0.05***	***0.02***	***1.00***	***1.00***
Sb-decolorized								
N6	**Colorless**	65.61	0.20	2.41	0.78	0.08		6.29
N9	**Colorless**	64.78	0.19	1.91	0.69	0.06	1.49	6.26
N13	**Colorless**	68.23	0.12	2.08	0.63	0.03		8.15
N14	**Colorless**	69.49	0.07	1.53	0.36		1.72	5.74
N23	**Colorless**	65.21	0.20	2.12	0.73	0.07	1.42	6.26
Average Sb-decolorized Tomis		*66.66*	*0.16*	*2.01*	*0.64*	*0.06*	*1.54*	*6.54*
STDEV		*2.08*	*0.06*	*0.32*	*0.17*	*0.02*	*0.16*	*0.93*
Sb-decolorized (Foy et al., 2004)		*71.00*	*0.06*	*1.94*	*0.34*	*0.02*	*0.43*	*5.56*
Sb-decolorized (Gliozzo, 2017)		*71.53*	*0.06*	*1.90*	*0.34*	*0.01*	*0.39*	*5.36*
Sb-decolorized (Silvestri et al., 2018)		*70.19*	*0.07*	*1.98*	*0.40*	*0.02*	*0.38*	*4.92*
N2	**Aqua blue**	67.21	0.36	2.23	0.81	0.04	1.86	7.19
Mn-decolorized								
N12	**Colorless**	69.45	0.08	2.62	0.88	2.48		7.94
N22	**Colorless**	67.87	0.08	2.17	0.39	1.62		6.49
N25	**Light green**	66.50	0.25	2.13	0.87	1.58		6.24
N34	**Colorless**	69.45	0.10	2.80	0.39	2.43		7.78
N40	**Colorless**	69.27	0.06	2.39	0.94	1.53		7.38
Average Mn-decolorized Tomis		*68.51*	*0.11*	*2.42*	*0.69*	*1.93*		*7.17*
STDEV		*1.30*	*0.08*	*0.29*	*0.28*	*0.48*		*0.76*
Mn-decolorized (Gliozzo, 2017)		*70.60*	*0.05*	*2.38*	*0.39*	*1.03*	*0.54*	*7.84*
Mn-colorless (Silvestri et al., 2018)		*69.96*	*0.07*	*2.63*	*0.33*	*1.41*	*0.56*	*7.88*

Table 1

PGAA results on *Tomis* glass samples - all concentrations expressed in wt%, empty cells mean below the detection limits

Sample ID	**Color**	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**
Detection limit [wt%]		***0.10***	***0.05***	***0.50***	***0.05***	***0.02***	***1.00***	***1.00***
Sb-Mn decolorized								
N3	**Colorless**	68.61	0.10	2.12	0.47	0.21	1.03	5.54
N17	**Colorless**	69.42	0.10	1.31	0.98	0.37		5.68
N24	**Colorless**	68.81	0.10	1.66	0.79	0.34		5.98
N37	**Colorless**	69.42	0.10	1.48	0.17	0.14		5.74
R17	**Colorless**	69.41	0.08	1.85	0.35	0.36		5.91
R37	**Colorless**	68.92	0.08	1.74	0.86	0.46		5.81
R45	**Colorless**	69.04	0.08	1.75	0.31	0.37	0.82	5.64
Average Sb-Mn colorless Tomis		*69.09*	*0.09*	*1.70*	*0.56*	*0.32*	*0.92*	*5.76*
STDEV Sb-Mn		*0.33*	*0.01*	*0.26*	*0.31*	*0.11*	*0.15*	*0.15*
Sb-Mn colorless (Gliozzo, 2017)		*70.32*	*0.09*	*2.18*	*0.51*	*0.28*	*0.52*	*5.92*
Sb-Mn colorless (Silvestri et al., 2018)		*69.69*	*0.09*	*2.28*	*0.48*	*0.41*	*0.57*	*6.40*
N1	**Colorless**	70.64	0.07	2.34	0.28	0.32		8.37
HIMT								
N4	**Olive-green**	66.51	0.21	2.53	1.64	1.61		6.25
Groupe 1 Foy (Foy et al., 2003) (4th c. AD)		*64.49*	*0.49*	*2.88*	*2.28*	*2.02*	*1.23*	*6.22*
RNCBGY2								
N1	**Colorless**	70.64	0.07	2.34	0.28	0.32		8.37
RNCBGY2 (1st-3rd c. AD) (Gliozzo et al., 2016)		*70.60*	*0.10*	*2.50*	*0.40*	*0.50*	*0.50*	*7.70*
N2	**Acqua blue**	67.21	0.36	2.23	0.81	0.04	1.86	7.19
HIT (Rehren and Cholakova, 2014)		*68.20*	*0.59*	*3.30*	*1.41*	*0.03*	*1.03*	*5.26*
HIT (Maltoni et al., 2018)		*65.82*	*0.49*	*2.71*	*2.46*	*0.22*	*1.11*	*6.03*

Table 1

PGAA results on *Tomis* glass samples - all concentrations expressed in wt%, empty cells mean below the detection limits

Sample ID	**Color**	**Na_2O**	**K_2O**	**SO_3**	**Sb_2O_3**	**CoO**	**Cl**
Detection limit [wt%]		***0.01***	***0.10***	***0.10***	***0.10***	***0.01***	***0.003***
Sb-decolorized							
N6	**Colorless**	20.52	0.61	0.33	1.20		1.14
N9	**Colorless**	20.60	0.59	0.40	1.39		1.19
N13	**Colorless**	17.88	0.61	0.50	0.49		0.95
N14	**Colorless**	17.82	0.35	0.27	0.57		1.20
N23	**Colorless**	20.37	0.58	0.41	0.90		1.19
Average Sb-decolorized Tomis		*19.44*	*0.55*	*0.38*	*0.91*		*1.13*
STDEV		*1.45*	*0.11*	*0.09*	*0.39*		*0.10*
Sb-decolorized (Foy et al., 2004)		*19.05*	*0.42*		*0.63*		
Sb-decolorized (Gliozzo, 2017)		*18.49*	*0.42*		*0.55*		
Sb-decolorized (Silvestri et al., 2018)		*19.53*	*0.42*		*0.81*		1.44
N2	**Aqua blue**	18.34	0.31	0.40			1.08
Mn-decolorized							
N12	**Colorless**	14.86	0.45				1.08
N22	**Colorless**	19.17	0.44				1.25
N25	**Light green**	20.30	0.49				1.16
N34	**Colorless**	14.83	0.47	0.40		0.03	1.99
N40	**Colorless**	16.31	0.72	0.40			1.60
Average Mn-decolorized Tomis		*17.09*	*0.51*	*0.40*			*1.41*
STDEV		*2.52*	*0.12*	*0.01*			*0.38*
Mn-decolorized (Gliozzo, 2017)		*15.73*	*0.67*				
Mn-colorless (Silvestri et al., 2018)		*15.31*	*0.54*				1.16

Table 1

PGAA results on *Tomis* glass samples - all concentrations expressed in wt%, empty cells mean below the detection limits

Sample ID	**Color**	**Na_2O**	**K_2O**	**SO_3**	**Sb_2O_3**	**CoO**	**Cl**
Detection limit [wt%]		***0.01***	***0.10***	***0.10***	***0.10***	***0.01***	***0.003***
Sb-Mn decolorized							
N3	**Colorless**	17.41	0.93	0.28	0.46		1.04
N17	**Colorless**	18.71	0.53		0.83		1.17
N24	**Colorless**	18.80	0.57	0.38	0.57		1.14
N37	**Colorless**	19.65	0.57	0.50	0.64		1.16
R17	**Colorless**	19.45	0.60		0.49		1.08
R37	**Colorless**	19.14	0.52	0.39	0.53		2.16
R45	**Colorless**	18.80	0.47	0.31	0.40		1.22
Average Sb-Mn colorless Tomis		*18.85*	*0.60*	*0.37*	*0.56*		*1.28*
STDEV Sb-Mn		*0.73*	*0.15*	*0.08*	*0.14*		*0.39*
Sb-Mn colorless (Gliozzo, 2017)		*18.27*	*0.55*		*0.30*		
Sb-Mn colorless (Silvestri et al., 2018)		*17.71*	*0.58*		*0.43*		*1.22*
N1	**Colorless**	16.11	0.53				1.05
HIMT							
N4	**Olive-green**	19.42	0.60				2.03
Groupe 1 Foy (Foy et al., 2003) (4th c. AD)		*19.12*	*0.41*				
RNCBGY2							
N1	**Colorless**	16.11	0.53				1.05
RNCBGY2 (1st-3rd c. AD) (Gliozzo et al., 2016)		*16.10*	*0.80*				
N2	**Acqua blue**	18.34	0.31	0.40			1.08
HIT (Rehren and Cholakova, 2014)		*18.20*	*0.38*				
HIT (Maltoni et al., 2018)		*19.24*	*0.40*				*1.27*