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## **GLASS FURNACES FROM SERDICA – AN EXAMPLE OF ROMAN PRACTICE OF GLASS MIXING**

Ivanov Mario, Anastasiaholakova Cholakova, Bernard Gratuze

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# ANNALES

du 21<sup>e</sup> CONGRÈS de l'ASSOCIATION  
INTERNATIONALE pour l'HISTOIRE du VERRE

3-7 Septembre 2018, Istanbul



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du 21<sup>e</sup> CONGRÈS de l'ASSOCIATION INTERNATIONALE  
pour l'HISTOIRE du VERRE

İstanbul 2018

*Editor*

Orhan Sevindik

*Editorial Committee*

Erdoğan Köse

Üzlifat Özgümüş

Ergün Laflı

Ömür Bakırer

Ömür Dünya Çakmaklı

İSTANBUL 2021

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*in memoriam*  
YOKO SHINDO

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## GLASS FURNACES FROM SERDICA – AN EXAMPLE OF ROMAN PRACTICE OF GLASS MIXING

The archaeological evidence of glass ateliers in the Bulgarian parts of the Roman provinces of Thracia and Lower Moesia is still limited. Glass working furnaces published so far come from the sites of Novae, Oescus, Parthicopolis and the fortresses near Gabrovo and village of Lozarevo.<sup>1</sup> Other ones excavated in Odessos, Philippopolis, Anchialus and Heraclea Sintica are briefly mentioned in the annual excavation reports, as well as in papers concerning glass production in general.<sup>2</sup> On the basis of finds and the study of glass vessel assemblages the existence of local glass working is also presumed for Iatrus, Nicopolis ad Istrum, the fortresses near Dichin and Sadovets.<sup>3</sup> As a whole, the

workshops belong mostly to the period of Late Antiquity, except for the furnaces from Oescus which are dated to the end of the 3<sup>rd</sup>–beginning of the 4<sup>th</sup> c. AD.

Until recently there was no archaeological proof for secondary glass working in the Roman town of Serdica. The archaeological campaigns during 2010–2012 brought to light new data in this respect. The rescue excavations were necessitated by the construction of an underground metro station, in the centre of the modern city. The archaeological team of the National Institute of Archaeology in Sofia investigated parts of several *insulae* of the Roman town.<sup>4</sup>

A large 4<sup>th</sup> c. private house – the so-called building A5 – is situated almost in the centre of the excavated area (Fig. 1). With different changes and repairs it survives until

1 DYCZEK 1999; OLSZAK 1998, 22–25, GENČEVA 1999, 97; KABAKČIEVA 1987; KOVACHEVA 1996; POPOVA 2017; KOYCHEVA 1990; DRAZHEVA 2002, 176.

2 DZHINGOV 1965, 16; CHOLAKOVA 2008; CHERNEVA 2014, 265; TORBATOV et al. 2015, 310; VAGALINSKI 2017, 301.

3 GOMOLKA 1978, 28; CHOLAKOVA 2008, 474; STAWIARSKA 2014, 65.

4 IVANOV 2011; IVANOV 2013; IVANOV 2016a.

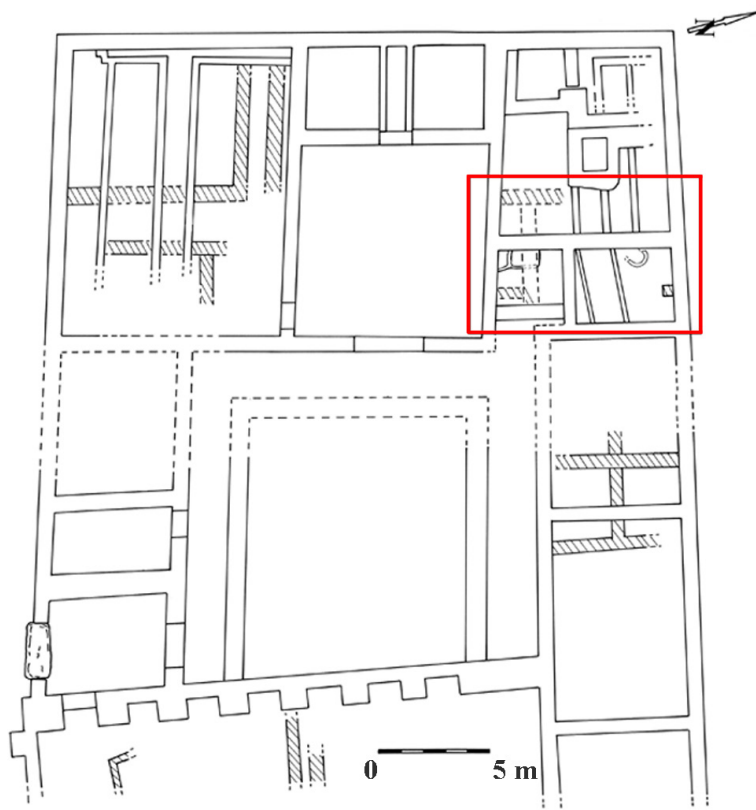


Fig. 1: Location of the glass furnaces (outlined in red) within the late antique house A5, drawing M. Ivanov.

the end of the 6<sup>th</sup> c. when it is destroyed by an earthquake. The building has many rooms situated around an inner courtyard with porticoes. Excavating the earlier periods of the building was possible only in limited areas because of the need of preserving the hypocaust systems, mosaic floors and courtyard pavement of the late antique house for further conservation and display. The discovered parts of 2<sup>nd</sup>-3<sup>rd</sup> c. walls indicate a different ground plan of the earlier building. During the excavations of the north-western part of the building, the remains of two furnaces for glass working were discovered (Fig. 2).

## DESCRIPTION

The two structures are synchronous and likely form part of a single installation consisting of a rectangular tank furnace and a smaller oval furnace. The tank furnace (Fig. 3.1) has two chambers and preserved overall dimensions of 1.90 m by 0.76 m. The inner size of the rectangular tank for glass melting is 1.20 m by 0.62 m. Its northern half is almost entirely destroyed by a trench of a later wall. Only the lower part of the northern wall is preserved intact. The

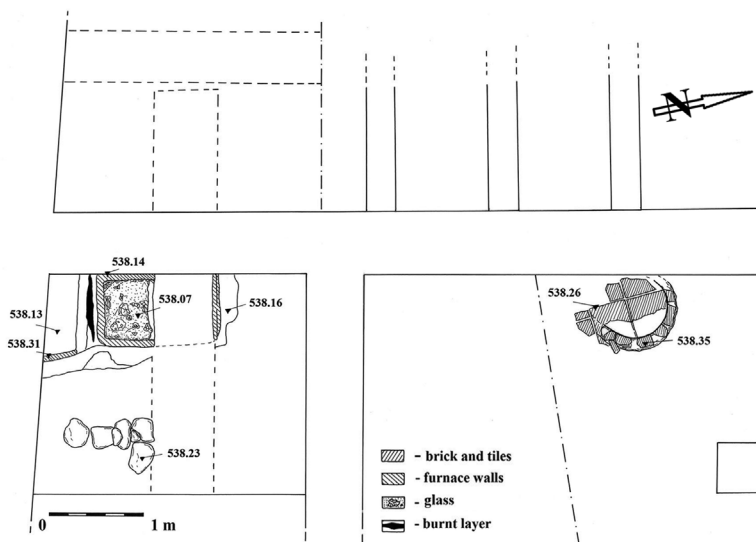


Fig. 2: Plan of the two glass furnaces, drawing M. Ivanov.

GLASS FURNACES FROM SERDICA – AN EXAMPLE OF ROMAN  
PRACTICE OF GLASS MIXING

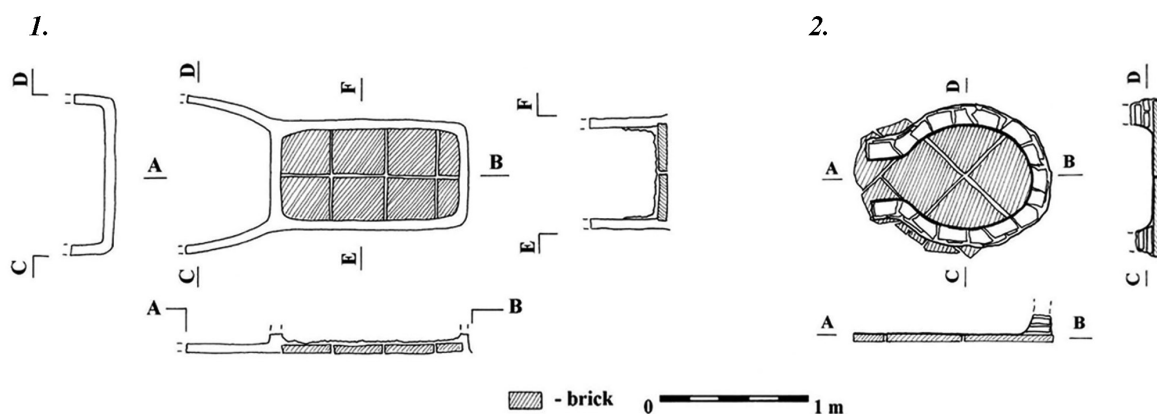


Fig. 3: Graphic reconstructions of the Serdica furnaces, drawing M. Ivanov.

firing chamber is situated to the south of the tank. Its exact dimensions remain unknown because the northern and western parts were destroyed by the walls of the so-called building A5.

The ground surrounding the tank furnace, up to a distance of 15–20 cm all around, is fired by the high temperature. The entire construction is dug in the ground to a depth of at least 20 cm, as indicated by the south cross-section and the preserved part of the east side of the firing chamber (Fig. 4). Accordingly, the working level around the tank furnace during the time of its operation is some 20–25 cm higher than the bottom level of the tank (at elevation 538.31/34). This walking level is marked by the yellowish-beige layer of sandy soil with traces of fire on it.

The southern half of the tank base is well preserved, and a large fragment of the destroyed northern part of the furnace shows that the base of the structure was constructed most probably of bricks and/or fragments of bricks bond with clay. The thickness of the bricks is approximately 4 cm while the overall thickness of the furnace base, includ-

ing the glass that has remained on it, is over 6.5–7 cm. The walls of the furnace are made of clay and have a thickness of 5.5 cm. Their inner surface which was exposed to the heat but not in direct contact with the glass melt has cracks and a vitrified layer, presumably due to the high temperature, and the interaction of the clay and the combustion fumes.<sup>5</sup>

During the excavations, a few large and numerous smaller pieces of the upper part of the tank furnace were found collapsed inside the melting chamber. Three parts of a broken sidewall, probably the western one, fit together and allow us to establish the level up to which the tank was filled – to at least 20 cm above the bottom of the tank. Accordingly, such a measurement helps to estimate an approximate minimum volume of melted glass during the final firing of the furnace at about 0.15 cubic metres, or 375 kg of glass.<sup>6</sup>

Inside the tank and in the area around the furnace a relatively small quantity of unworked transparent glass chunks was found (0.8 kg). Interestingly, the chunks represent a diversity of colours – from clear colourless and light yellowish-green to darker green.

<sup>5</sup> REHREN and PERINI 2005, 186.

<sup>6</sup> Calculated according to an average density of soda-lime-silica glass of 2.5 g/cm<sup>3</sup>.



Fig. 4: The tank furnace, photo M. Ivanov.



Fig. 5: The oval furnace, photo M. Ivanov.

These are apparently pieces of glass detached from the furnace walls and floor, possibly left behind from the eventual cleaning of the tank before its demolition. The only small finds excavated within the area immediately around the furnace are two glass moil

fragments and a thread that was formed by the removal of impurities from the batch. They are made of visually identical transparent glass with a bluish tint. Importantly, the chemical composition of the analysed moil differs from that of the glass chunks from the furnace, hence ruling out the possibility that the wasters were by-products of the working process related to final furnace batch (see below). Probably they were part of the stocked cullet used as a raw material for re-melting in the tank.

The second furnace (Fig. 3.2) was excavated at 3.60 m to the north of the tank furnace. Parts of the west and south walls of the structure were destroyed by the construction of the 4<sup>th</sup> c. building A5. The furnace is oval in plan with preserved outer dimensions of 1.0 by 0.85 m. Four bricks and some fragments of bricks form the floor of its chamber. The construction of the walls, 10 cm thick, is of tile fragments and clay. The preserved height of the structure, including its base, is 20 cm. The inner surface of the chamber has a thin clay lining (Fig. 5). The bricks underneath were burnt black by the high temperature. Only a brick-red layer of the chamber wall rubble was found in the furnace, mixed with single

fragments of tiles. The opening of the firebox was most probably from the southwest; this part was entirely destroyed during construction of the 4<sup>th</sup> c. building. The lower part of the structure probably was slightly dug in the burnt layers of the previous building period of the house. Such a floor level of the circular furnace corresponds to the elevation of the walking/floor level around the already mentioned rectangular tank furnace.

The described furnaces should be considered as functional parts of a small workshop for secondary glass working. Their corresponding levels and the alignment in one and the same axis confirm the assumption for their simultaneous use, likely for two different processes within the same workshop. At 2.0 m to the west of the furnaces there was a wall surrounding the workshop from this side. Only the trench of it was registered because the building material of the wall was later extracted for reuse. It follows north-south direction, with a thickness of 0.55 m. The stratigraphic cross section in this area shows that the wall existed before the operation of the furnaces and probably belongs to the earlier building in this area. It was demolished during the construction of the 4<sup>th</sup> century building. The other walls of the workshop building remain unknown, as well as the exact plan and dimensions of its space because of the limited area of the excavations in this place.

## CHRONOLOGY

The date of the presented furnaces could be established only on the basis of their stratigraphic position because of the complete lack of any datable finds in and around the structures. Both furnaces are dug in a layer of a wood and mudbrick con-

struction destroyed during a fire. This layer is associated with the mid-3<sup>rd</sup> c. AD raids of the Goths which caused substantial damages in Serdica. Accordingly, this event is a *terminus post quem* for the functioning of the glass workshop. The upper possible time limit for the production activities is marked by a mortar layer which corresponds to the construction level of the building A5 from the beginning of the 4<sup>th</sup> c. AD the walls of which partly cut through both furnaces. Such a timespan could be further specified. Most probably the furnaces were active in a short period during the rebuilding activities in the area, immediately after the raids. The north half of the tank furnace was destroyed by the construction of a new wall probably very soon after the Goth incursions. Later – during the construction of the new building in the beginning of the 4<sup>th</sup> c. – the building material of this wall was extracted for reuse. If this supposition is correct, the use of glass furnaces could be dated to around the middle of the 3<sup>rd</sup> c. or shortly after it.

## PARALLELS

Circular furnaces are known from sites all over the Roman Empire, for example-Thessaloniki, Siscia, Augusta Raurica, Spolverino, as well as Oescus and Novae in Bulgaria.<sup>7</sup> Structures of this kind are considered as pot furnaces for melting small amounts of glass for making vessels and other glass items.<sup>8</sup> The case of the rectangular furnaces is more complicated. The type appears in the 2<sup>nd</sup> c. AD and it is chronologically later than the circular ones.<sup>9</sup> Some of the rectangular structures most probably served for anneal-

7 ANTONARAS 2016, 25, 174, cat. № 64; LELJAK and LAZAR 2013, 116–117; FISCHER 2009, 47–50; SEBASTIANI and DERRICK 2016, 280; KABAKČIEVA 1987, 171–172; STAWIARSKA 2014, 56.

8 LEPRI and SAGUI 2017, 170; FISCHER 2009, 77.

9 NENNA 2008, 62.

1.	oxide	chunks mean (n=6)	moil
wt%	SiO <sub>2</sub>	69.6	70.3
	Na <sub>2</sub> O	17.9	16.0
	Al <sub>2</sub> O <sub>3</sub>	2.28	2.52
	CaO	6.15	7.81
	K <sub>2</sub> O	0.60	0.50
	MgO	0.58	0.53
ppm	P <sub>2</sub> O <sub>5</sub>	736	1137
	Cl	1.10	0.95
wt%	Fe <sub>2</sub> O <sub>3</sub>	0.64	0.43
	TiO <sub>2</sub>	1155	747
ppm	ZrO <sub>2</sub>	83	54
	MnO	1458	3986
	Sb <sub>2</sub> O <sub>3</sub>	5818	1722
	CoO	4	5
	CuO	25	20

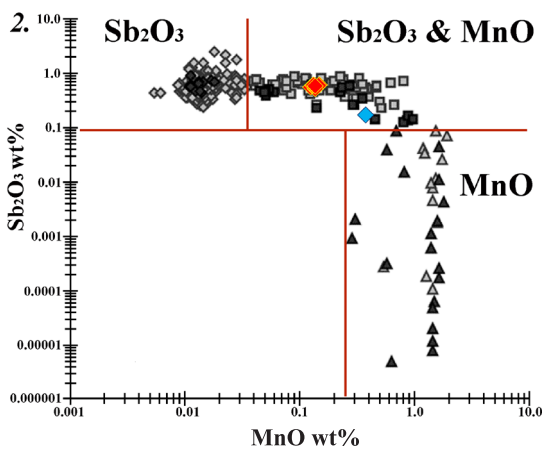


Fig. 6:1. Chemical composition of the glass fragments found at the tank furnace, and a plot of their MnO and Sb<sub>2</sub>O<sub>3</sub> levels (2.) – chunks in red; moil in blue – compared to Roman colourless glass from Gaul (after GRATUZE 2018, Fig. 6).

ing vessels, while the purpose of the other ones is for melting raw glass or recycling glass cullet, as for example the tank furnaces from Augusta Raurica, Verona, Bonn and Plaudren.<sup>10</sup> The most important feature indic-

ative of the function is the presence of glass adhered on the walls and bottom of the furnace.<sup>11</sup> Probably the closest parallels of the Serdica structure are the tank furnace from Ulpia Traiana Sarmizegetusa, presumed to be used for making windowpanes, and the furnaces from Plaudren and Bonn.<sup>12</sup> The tank furnaces from Philippopolis and Odesos could be of similar shape but the lack of appropriate descriptions and documentation makes impossible any detailed comparison.<sup>13</sup>

### ARCHAEOMETRIC ANALYSIS

Four glass chunks and one moil fragment were selected for scientific analysis.<sup>14</sup> This selection covered the range of colours and tints seen in the overall volume of unworked glass pieces excavated in the furnace: from almost colourless to darker green. However, only relatively small compositional variations were found between the chunk samples. Such a slight chemical heterogeneity and the colour diversity could result from a variable degree of contamination of the glass from the furnace lining, mixing of chunks from different batches (multiple operational cycles), or poor homogenisation of a single melt, as well as variable temperature and redox conditions within a single batch which would affect the range of the glass hues.

10 FISCHER 2009, 78–79; LEPRI and SAGUI 2017, 170; FOLLMANN-SCHULZ 1991, 39; TRISTE and DARE 2005, 12–16.

11 NENNA 2008, 62; LEPRI and SAGUI 2017, 171.  
 12 BĂEȘTEAN and HÖPKEN 2009; FOLLMANN-SCHULZ 1991, 39; TRISTE and DARE 2005, 12–16.  
 13 TRAK and CHERNEVA 2011, 102, 105, see the picture on p. 15; STAWIARSKA 2014, 70.  
 14 Analyses were carried out using LA-ICPMS technique at the laboratory of IRAMAT-CEB. For details of the analytical protocol see GRATUZE 2016, 181–185; for details of the standard measurements see CHOLAKOVA, REHREN and FREESTONE 2016, 627–628 (analytical run ‘LA-ICPMS 2012’). Two of the chunk samples demonstrated a higher degree of compositional heterogeneity, and therefore they were considered as four individual results; hence, the entire analytical set (including the moil) consists of seven results in total.

The glass from the Serdica furnace belongs to the Roman antimony decolourised composition, with an average of nearly 0.6 wt%  $\text{Sb}_2\text{O}_3$ , and relatively high levels of lime and alumina, as well as of certain sand-deriving minor and trace oxides (Fig. 6.1).<sup>15</sup> The presence of manganese in concentrations of approximately 0.15 wt% MnO exceeds the expected natural background levels, and still it is lower than the level of intentionally added decolouriser.<sup>16</sup> Accordingly, the chunks from the furnace represent a mixed batch consisting of predominantly Sb-decolourised glass, and adulterated with a certain amount of manganese containing glass. It is not possible to determine whether this is a mixture of two stocks of different fresh raw glasses or a combination of (diverse?) fresh glass and cullet. Nevertheless, given the archaeological context of the furnace, the latter option is more likely.

The composition of the moil fragment differs from the chunks by its  $\text{Sb}_2\text{O}_3$ –MnO ratio, with a significant prevalence of manganese oxide, and also by its higher alumina and lime values (Fig. 6.1). It is compositionally very close to the naturally coloured Roman glass makeup,<sup>17</sup> with a certain incorporated amount of manganese, although the antimony oxide content (0.17 wt%  $\text{Sb}_2\text{O}_3$ ) indicates that this glass has its own recycling

history. Since the moil cannot be a waster left behind from the blowing of the glass from the furnace, it strongly suggests that mixing and re-melting of pre-collected cullet, and even multiple cycles of cullet reuse, likely mixed with/added to fresh raw glass was part of the working practices of the craftsmen operating the furnace, as seen at other Roman secondary glass workshops and assemblages<sup>18</sup> (Fig. 6.2).

It is important to stress that the analysed samples do not display evidence of significant contamination (e.g. from fuel vapour and ash, from furnace lining, blowing iron, or traces of glass colourants). This implies that probably it is not a case of gradual spoiling of the glass due to overly repeated and/or indiscriminate recycling that would have been necessitated by severe economic conditions, such as insufficient raw glass supplies.<sup>19</sup> The Serdica workshop is rather an example of a well-established practice of glass mixing aimed at an optimised use and recycling of a range of locally available but still carefully selected materials (fresh raw glass, pre-collected cullet, production waste) in the context of a prosperous Roman provincial town.

## FUNCTION AND CONCLUSION

The presented analytical data indicate the presence of different glass compositions which supports the assumption of recycling cullet glass, probably mixed with fresh raw glass, as evidenced by the negligible levels of contamination. The short-term activity of the workshop could explain the absence of accumulated archaeological layer related to the operation of the furnaces, as well as the lack of any traces of repairs, multiple layers

15 FOY, THIRION-MERLE and VICHY 2004, 170–174; GRATUZE 2018, Sub-group Sb1b, Fig. 7a, Fig. 8; PAYNTER and JACKSON 2019, Fig. 6.

16 As demonstrated by experimental studies, the natural background levels of manganese in the glassmaking sands result in a MnO content of <0.1 wt% in the glass (BREMS and DEGRYSE 2014, 38). Other studies suggest that the natural sand-derived manganese content of the Roman antimony decolourised composition is around 0.025 wt% MnO (SCHIBILLE, STERRETT-KRAUSE and FREESTONE 2017, 1230), and 0.033 wt% MnO (GRATUZE 2018, 351); values indicative of an intentional addition of manganese as a decolourant are being defined as >0.5 wt% (JACKSON 2005, 771), or slightly higher (approx. >0.8 wt% in GUÉRIT and GRATUZE 2016, 48; GRATUZE 2018, 352).

17 FREESTONE et al. 2015, Table 6.

18 FREESTONE 2015, 30–34; FREESTONE et al. 2015, 87–90; PAYNTER and JACKSON 2016, 37.

19 JACKSON and PAYNTER 2015, 83.

of lining, etc. in the construction of the furnaces. Furthermore, the location of the workshop almost in the centre of the town, away from the craft and market urban areas, and the striking scarcity of glass-blowing waste are arguments against the hypothesis for market oriented production of blown vessels. On the other hand, it is clear that a considerable amount of glass was processed in the tank furnace. The parallel of Sarmizegetusa furnace as well as the chronology of the Serdica one allow supposing identical function for the two workshops – supplying the new construction activities with architectural glass made on the spot. The location of the Serdica workshop is also indicative in this respect. It is placed within the remains of a residential building probably owned by the family of Arii – wealthy people and city councillors, being among the most prominent citizens of Serdica in the early 3<sup>rd</sup> c. AD.<sup>20</sup>

As a rule, glass workshops frequently associated with other crafts using fire were set up outside the city walls or at the margins of inhabited quarters. The situation changes later when these activities most often move closer to the central areas using abandoned public buildings.<sup>21</sup>

Cast and blown glass techniques are used for making windowpanes in antiquity.<sup>22</sup> It is generally accepted that the cast windowpanes were predominant during the first three centuries AD. The archaeological data for blown windowpanes are rare before the end of the 3<sup>rd</sup> c. AD, and most probably they became common during the 4<sup>th</sup> c. AD.<sup>23</sup> The

lack of moils and any other glass blowing waste, compatible with the chemical composition of the glass from the tank, could be seen as evidence for the use of the older method of casting windowpanes. If this supposition is correct, the tank furnace should have been used for re-melting glass sherds and waste from the destroyed buildings and probably mixing it with raw glass while the circular furnace was possibly needed for further process of casting and forming the windowpanes.

As mentioned above, the volume of glass melted in the tank furnace from Serdica could be estimated at 0.15 m<sup>3</sup>, at least. Assuming an average thickness (or possibly higher than average) of approximately 0.5 cm for cast Roman windowpanes allows a conservative estimate of an overall area of approximately 30 m<sup>2</sup> of flat glass sheets which could have been produced from a single batch in the tank. Of course, this hypothetical calculation depends also on certain other, unknown parameters such as loss of glass, number of defective panes, etc. Nevertheless, it gives a good idea about the approximate capacity of the furnace and the scale of the workshop's output.

The archaeological and archaeometric evidence of the Serdica furnaces present a comprehensive picture of a short-time operating workshop for secondary glass working. Such production structures emerge in cases of necessity of significant amounts of architectural glass to supply new constructions or rebuilding activities in a Roman town. Most often the furnaces are intended for making window glass, but there are examples for the production of mosaic tesserae too. Further researches and new discoveries will bring additional information on this topic.

<sup>20</sup> IVANOV 2016b.

<sup>21</sup> PRICE 2005, 172–174; ANTONARAS 2016, 24–25.

<sup>22</sup> FOY and FONTAINE 2008; PAYNTER and DUNGWORTH 2011, 22–23.

<sup>23</sup> FOY and FONTAINE 2008, 409–410, 430; ALLEN 2002, 102.

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