



HAL
open science

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

Ivanov Mario, Anastasiaholakova Cholakova, Bernard Gratuze

► **To cite this version:**

Ivanov Mario, Anastasiaholakova Cholakova, Bernard Gratuze. GLASS FURNACES FROM SERDICA – AN EXAMPLE OF ROMAN PRACTICE OF GLASS MIXING. Orhan Sevindik. ANNALES du 21e CONGRÈS de l'ASSOCIATION INTERNATIONALE pour l'HISTOIRE du VERRE İstanbul 2018, AIHV, pp.207-219, 2021, 978-605-7880-10-9. hal-03482503

HAL Id: hal-03482503

<https://hal.science/hal-03482503>

Submitted on 16 Dec 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



İSTANBUL UNIVERSITY
CERRAHPAŞA

ANNALES

du 21^e CONGRÈS de l'ASSOCIATION
INTERNATIONALE pour l'HISTOIRE du VERRE

3-7 Septembre 2018, Istanbul



ANNALES

du 21^e 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

ANNALES

du 21^e CONGRÈS de l'ASSOCIATION INTERNATIONALE
pour l'HISTOIRE du VERRE

Istanbul, 03-07 Septembre 2018

Editor: Orhan Sevindik

Editorial Committee: Erdoğan Köse, Üzlifat Özgümüş, Ergün Laflı, Ömür Bakırer,
Ömür Dünya Çakmaklı

Scientific Committee: Ali Akın Akyol, Anastassios Antonaras, Şeniz Atik, Ömür Bakırer,
Janet Duncan Jones, Emel Erten, Semavi Eyice, Sylvia Fünfschilling, Sid Goldstein, Yael
Gorin Rosen, Binnur Gürler, Julian Henderson, Despina Ignatiadou, Ergün Laflı, Chris
Lightfoot, Teresa Medici, M.Dominique Nenna, Jennifer Price †, Ann De Pury-Gysel,
Rabia Özakın, Eva Marianne Stern, Sophie Wolf

Special thanks:

Ergün Laflı prepared the First, Second and Third Circulars.

E.Marianne Stern corrected the English version of Preface and Brigitte Demierre

Prihodkine translated the English version into French.

Nuri Aydın (*Rector, Istanbul University-Cerrahpasa*)

Mahmut Ak (*Rector, Istanbul University*)

Hami Eyilik- Efeglass (*sponsor*)

Serra Kanyak

Computer layout: Orhan Sevindik

Cover Design: Emir Bostancı

Printed by: Vadi Grafik Tasarım ve Reklamcılık Ltd. Şti.

İvedik Organize San. 1420. Cad. No: 58/1-2-3-4-5

Ostim - Y. Mahalle / ANKARA - Tel: 0312 395 85 71-72

Certificate Number: 47479

No. of copies: 250

Publisher: AIHV

Association Internationale pour l'Histoire du Verre

International Association for the History of Glass

<http://www.aihv.org>

Secretariat: Via A. Alciato 2 I-27100 Pavia, Italy

© AIHV and authors - 2021

ISBN: 978-605-7880-10-9

*Cover image: Roman handle applique found in the Marmaray-Metro
Excavations - Istanbul. 4th Century*

in memoriam
YOKO SHINDO

CONTENTS

PREFACE- Sylvia FÜNFSCHILLING	11
PRÉFACE- Sylvia FÜNFSCHILLING	13
VORWORT- Sylvia FÜNFSCHILLING	15
2nd - 1st Millenium BC/Bronze Age/Iron Age/ Archaic/Late Classical Glass	
<i>HENDERSON Julian, CHENERY Simon, MATSUMURAKI Kimiyoshi, EVANS Jane, OMURA Sachihiro</i>	
DID THE HITTITES MAKE GLASS?	17
<i>ENGİN Atilla, ATİK Şeniz, ÖZER Ali</i>	
MIDDLE BRONZE AGE VITREOUS MATERIAL OF OYLUM HÖYÜK AND NEW FINDINGS.....	35
<i>BROSCHAT Katja</i>	
GLAS AUS DEM GRAB DES TUTANCHAMUN	49
<i>ŞENYURT Yücel, ERTEN Emel</i>	
A GLASS HORSE RHYTON FROM AŞAĞI SALAT MOUND IN DİYARBAKIR, TURKEY	61
<i>JONES Janet, MARSH Ben</i>	
A GLASS-BASED HISTORY OF GORDION	69
<i>KOLESNYCHENKO Anzhelika, KIOSAK Dmytro</i>	
THE ANCIENT GLASS-WORKSHOP OF YAHORLYK SETTLEMENT IN THE NORTHERN PONTIC REGION	81
<i>IGNATIADOU Despina</i>	
THE FACES ON THE PENDANTS	95

Roman Glass

LIGHTFOOT Christopher

ANCIENT GLASS IN ROMAN ITALY BEFORE THE INVENTION OF BLOWING: CAST MOSAIC GLASS..... 109

ŠTEFANAC Berislav

ROMAN NON-BLOWN GLASS FROM ZADAR (CROATIA)..... 119

NENNA Marie-Dominique

THE GLASS FROM HEGRA (MADÂ'IN SÂLIH, SAUDI ARABIA)..... 133

DIANI Maria Grazia, REBAJOLI Francesca

CONTRIBUTION TO THE MAP OF DISTRIBUTION OF HEAD-SHAPED VESSELS IN ITALY: AN UNCONVENTIONAL BEAKER FROM VERCELLI (PIEDMONT)..... 141

LAZAR Irena

NEW FINDS OF ROMAN HIGH QUALITY GLASS FROM ROMULA (PANNONIA) 149

ERTEN Emel

GLASS FROM OLBA IN ROUGH CILICIA..... 161

STERRET-KRAUSE Allison

RECONSTRUCTING LIFE FROM THE LITTER IN POMPEII'S SOUTHWEST CORNER: GLASS FROM THE EXCAVATIONS OF THE POMPEII ARCHAEOLOGICAL RESEARCH PROJECT: PORTA STABIA..... 171

HANAR Elif

MOLD-BLOWN GLASS VESSELS IN DİYARBAKIR MUSEUM 183

ZACHARIAS Nikolaos, OIKONOMOU Artemios, ARAPOGIANNI Xenia

TECHNOLOGY AND USE OF GLASS DURING THE CLASSICAL - HELLENISTIC TIMES:A CASE STUDY OF GLASS KNUCKLEBONES 195

IVANOV Mario, CHOLAKOVA Anastasia, GRATUZE Bernard

GLASS FURNACES FROM SERDICA - AN EXAMPLE OF ROMAN PRACTICE OF GLASS MIXING 207

ÇELİKBAŞ Ersin, KELEŞ Vedat

GLASS FINDS FROM LATE ROMAN HOUSE IN PAPHLAGONIAN HADRIANOPOLIS 221

BULJEVIĆ Zrinka

MOULD-BLOWN GLASS VESSELS FROM SALONA 233

AKKUŞ KOÇAK Emine

GLASS WORKSHOPS AND GLASS PRODUCTION IN METROPOLIS (IONIA) 245

*TRAVIGLIA Arianna, PANIGHELLO Serena, MORETTO Ligia, ORSEGA Emilio Francesco,
BERNARDONI Anna, FLOREANI Stefi, MORO Giulia, MANDRUZZATO Luciana*

**PICKING UP THE HINT: RAW GLASS CHUNKS AND GLASS WASTES FROM
PLOUGHSOIL COLLECTION IN AQUILEIA (ITALY)..... 255**

GRÜNEWALD Martin

**GLÄSERNE GRABFUNDE SPÄTANTIKER ZEIT AUS DEM RHEINISCHEN
BRAUNKOHLEREVIER (DEUTSCHLAND)..... 265**

Late Roman/Byzantine /Early Islamic/Medieval Glass

ŽIVANOVIĆ Miloš

GLASS WORKING ACTIVITIES IN LATE ROMAN DOCLEA (MONTENEGRO)..... 283

COSYNS Peter, CEGLIA Andrea, THIENPONT Hugo, von WARTBURG Marie-Louise
**A LATE ANTIQUE GLASS WORKSHOP AT THE APHRODITE SANCTUARY OF
PALAEPAPHOS, KOUKLIA (CYPRUS) 291**

SCHINTLMEISTER Luise

**GLASS OF A LATE ANTIQUE-MEDIEVAL URBAN QUARTER IN EPHEOS/TURKEY
(4TH/5TH–12TH CENTURIES CE) - PRELIMINARY REPORT 307**

GORIN ROSEN Yael

**SECONDARY GLASS PRODUCTION IN ISRAEL - BRIEF SUMMARY
OF THE FINDS AND NEW DISCOVERIES 319**

RUMYANTSEVA Olga, YUBITCHEV Mikhail, PETRAUSKAS Oleg,

CHERVYAKOVSKAYA Maria, KHANIN Dmitry, TRIFONOV Alexander
**‘BARBARIAN’ BEAKERS WITH FACET CUT DECORATION: COMPOSITION,
ORIGIN, SOCIAL AND CULTURAL CONTEXT 333**

BAYBO Selda

**EIN ÜBERBLICK ÜBER DIE GLASFUNDE VON LIMYRA (1969-2012)
UND DIE BEFUNDE ZUR GLASPRODUKTION AUS DEN OSTTORGRABUNGEN 349**

STERN E. Marianne Stern

GLASS FROM THREE BYZANTINE CHURCHES AT ANCIENT ANEMURIUM (TR) . 363

GENÇ Deniz, AKYOL Ali Akın

**ARCHAEOLOGICAL INVESTIGATIONS OF THE EARLY BYZANTINE
SITE SIDE GLASS FINDS..... 375**

<i>CHINNI Tania, FERRERI Debora, CIRELLI Enrico</i> GLASSWORKING IN CLASSE: WORKING DEBRIS FROM THE SOUTHERN DISTRICT	389
<i>COUSINAS Nadia</i> NEW LIGHT ON THE EARLY BYZANTINE GLASS FROM ELEUTHERNA PYRGI (CRETE)	399
<i>TAŞTEMUR Emre, DİNÇ Münteha</i> GLASS OBJECTS FOUND IN AKMONIA CITY SURFACE RESEARCH	417
<i>STORCHAN Benyamin, GANOR Adrienne</i> GLASS, POTTERY, PLASTER AND IRON: PRELIMINARY TECHNOLOGICAL INSIGHTS FROM THE WINDOWS AT THE CHURCH OF THE GLORIOUS MARTYR IN THE HOLY LAND	433
<i>NOBACK Andreas, GROBE Lars O, LANG Franziska</i> MODELLING THE EFFECTS OF DAYLIGHT SCATTERING BY WINDOW GLASS: THE CASE OF SIXTH CENTURY HAGIA SOPHIA IN ISTANBUL	443
<i>BAKIRER Ömür, ERCİYAS D. Burcu</i> MEDIEVAL GLASS FINDS FROM THE KOMANA EXCAVATIONS NEAR TOKAT, TURKEY	457
<i>DE JUAN ARES Jorge, SCHIBILLE Nadine</i> LATE ROMAN AND EARLY ISLAMIC GLASS IN SPAIN: PRODUCTION AND CONSUMPTION	471
<i>WINTER Tamar</i> OPULENCE ON THE DESERT FRINGES? GLASS ASSEMBLAGES OF THE EARLY ISLAMIC PERIOD FROM THE NORTHEASTERN NEGEV, ISRAEL	485
<i>KÜRTÖSI Brigitta Maria</i> A DIVERSE PRODUCTION METHOD OF GOLD GLASS MOSAIC TESSERAЕ FROM MEDIEVAL HUNGARY, ROYAL BASILICA OF ALBA REGIA/SZÉKESFEHÉRVÁR	497
<i>STOLYAROVA Ekaterina</i> MEDIAEVAL GLASS BRACELETS IN RUS' (ACCORDING TO THE FINDS IN THE TOWNS OF THE NORTH-EAST OF RUS')	507
Islamic Glass	
<i>VALIULINA Svetlana</i> ISLAMIC GLASS OF BILYAR: IMPORT AND PRODUCTION	521

ARVEILLER-DULONG Véronique

**LES VERRES ISLAMIQUES D'ANTINOÉ (MOYENNE-ÉGYPTE)
CONSERVÉS AU LOUVRE: UN APERÇU 529**

GEYİK Gül

ISLAMIC GLASS IN SOME ANATOLIAN MUSEUMS 539

ÖZAKIN Rabia, CANAV-ÖZGÜMÜŞ Üzlifat, KANYAK Serra, ÇELİK İzzet Umut

DECORATIVE WINDOW GLASS FROM SOME OTTOMAN TOMBS IN ISTANBUL .. 549

European Glass

TOPIĆ Nikolina

LATE MEDIEVAL GLASS LAMPS FROM DUBROVNIK 559

MEDICI Teresa

**A NOTE ON LATE MEDIEVAL AND EARLY MODERN
OPAQUE RED GLASS VESSELS 569**

JARGSTORF Sibylle

FICHTELGEBIRGSGLAS 579

FONTAINE-HODIAMONT Chantal, WOUTERS Helena, LEFRANCQ Janette

**LE VERRE VÉNITIEN SOUFFLÉ-MOULÉ AUX ARMES D'ANVERS, DEUXIÈME
MOITIÉ DU XVI^e SIÈCLE. APPROCHE TYPOLOGIQUE, ANALYTIQUE
ET HISTORIQUE 587**

LIKHTER Ju. A.

**GLASS FAÇON DE VENISE FROM THE EXCAVATIONS IN MOSCOW
AND OTHER CITIES (VYAZMA, MANGAZEYA) 597**

JOVIĆ GAZIĆ Vedrana

**MAPPING OF THE 17TH CENTURY GLASS LAMPS ON THE EASTERN
ADRIATIC COAST - CESENDELLO TYPE (HANGING LAMP) 609**

ANTONARAS Anastassios

**OTTOMAN-ERA (17TH AND 19TH-CENTURY), GLASS LAMPS FROM
CHURCH A' IN PLATAMONAS CASTLE 621**

KOS Mateja

**GEORG FRANZ KREYBICH AND HIS TRAVEL TO LJUBLJANA
(LAIBACH IN KRAIN) IN 1681 629**

COSYNS Peter, DE VOS Annemie, CEGLIA Andrea, WARMENBOL Eugène
**THE ALEXANDER MEDALLION OF THE MAS, ANTWERP
(BELGIUM) RECONSIDERED 637**

General Themes

ŠTEFANAC Marko, ŠTEFANAC Berislav
**EXPERIMENTAL APPROACH TO MAKING EARLY ROMAN
FREE-BLOWN GLASS FORMS..... 649**

LARSON Katherine A.
**BUILDING A COLLECTION: RAY WINFIELD SMITH AND
THE CORNING MUSEUM OF GLASS 657**

INDEX OF AUTHORS..... 669

PHOTOGRAPHS 671

IVANOV Mario, CHOLAKOVA Anastasia, GRATUZE Bernard

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.¹ 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.² 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.³ 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 3rd–beginning of the 4th 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.⁴

A large 4th 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.

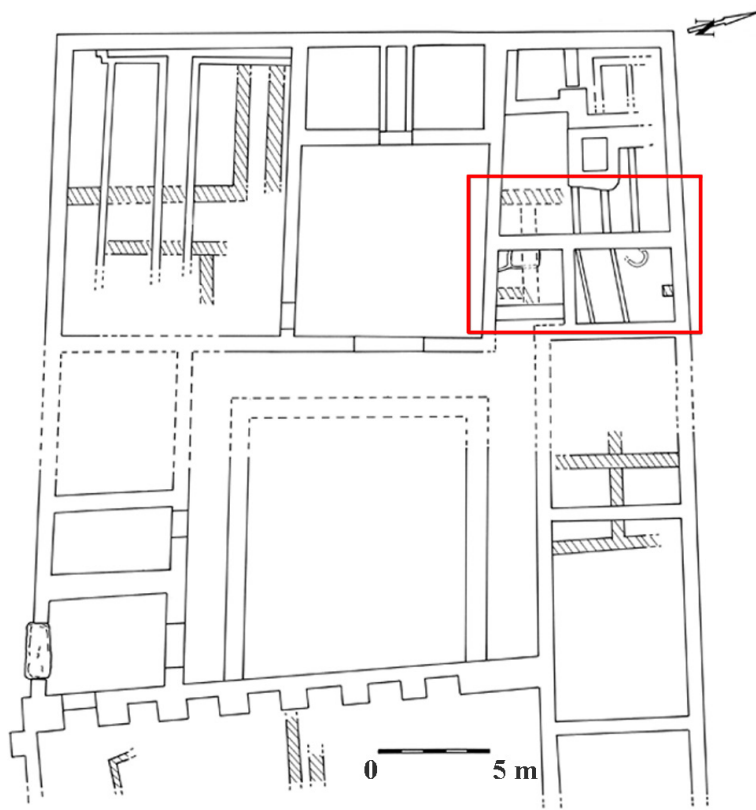


Fig. 1: Location of the glass furnaces (outlined in red) within the late antique house A5, drawing M. Ivanov.

the end of the 6th 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 2nd-3rd 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

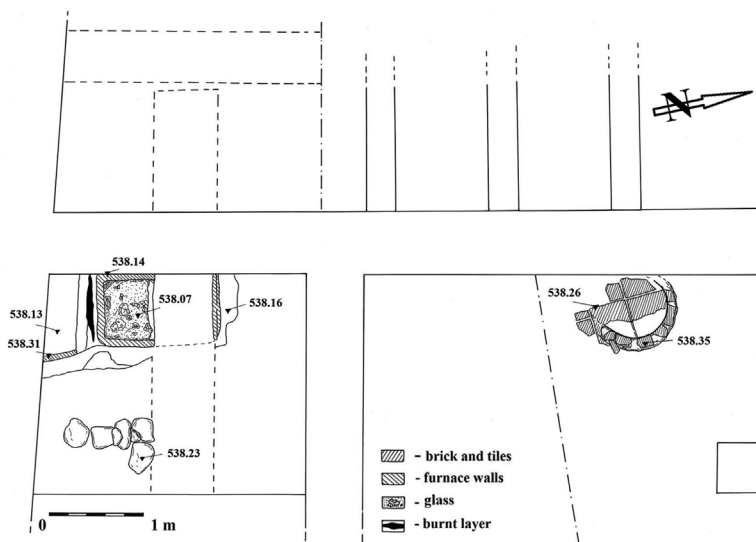


Fig. 2: Plan of the two glass furnaces, drawing M. Ivanov.

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

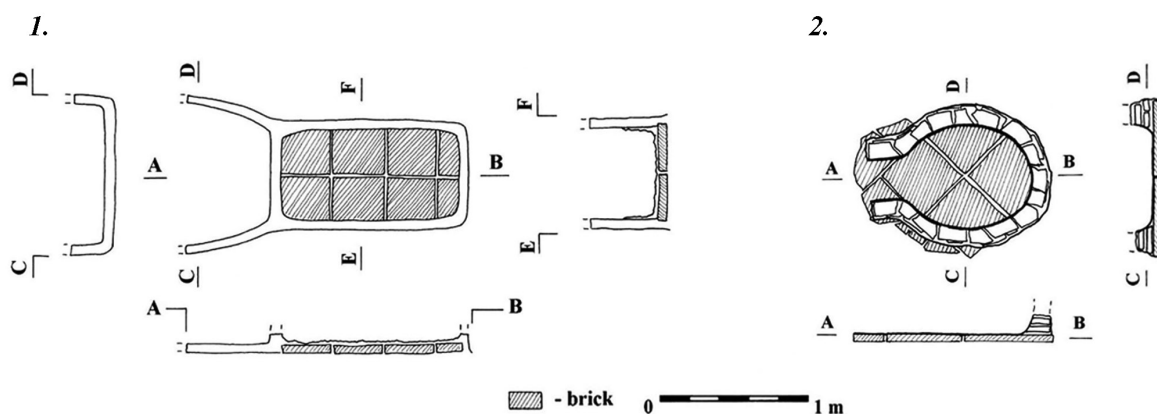


Fig. 3: Graphic reconstructions of the Serdica furnaces, drawing M. Ivanov.

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.⁵

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.⁶

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.

⁵ REHREN and PERINI 2005, 186.

⁶ Calculated according to an average density of soda-lime-silica glass of 2.5 g/cm³.



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 4th 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 4th 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 4th 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-3rd 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 4th 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 4th 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 3rd 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.⁷ Structures of this kind are considered as pot furnaces for melting small amounts of glass for making vessels and other glass items.⁸ The case of the rectangular furnaces is more complicated. The type appears in the 2nd c. AD and it is chronologically later than the circular ones.⁹ 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 ₂	69.6	70.3
	Na ₂ O	17.9	16.0
	Al ₂ O ₃	2.28	2.52
	CaO	6.15	7.81
	K ₂ O	0.60	0.50
	MgO	0.58	0.53
ppm	P ₂ O ₅	736	1137
	Cl	1.10	0.95
wt%	Fe ₂ O ₃	0.64	0.43
	TiO ₂	1155	747
ppm	ZrO ₂	83	54
	MnO	1458	3986
	Sb ₂ O ₃	5818	1722
	CoO	4	5
	CuO	25	20

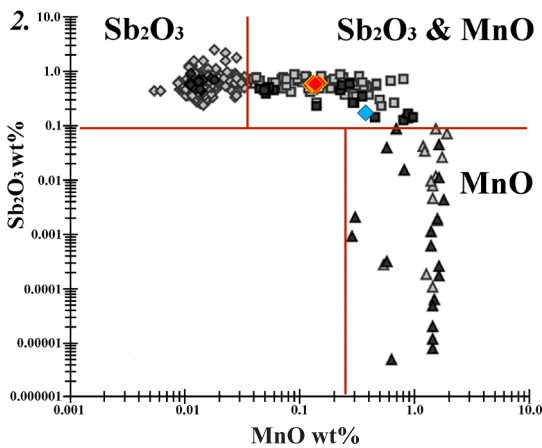


Fig. 6:1. Chemical composition of the glass fragments found at the tank furnace, and a plot of their MnO and Sb₂O₃ levels (2.) – chunks in red; moil in blue – compared to Roman colourless glass from Gaul (after GRATUZE 2018, Fig. 6).

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.¹⁰ The most important feature indic-

ative of the function is the presence of glass adhered on the walls and bottom of the furnace.¹¹ 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.¹² 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.¹³

ARCHAEOMETRIC ANALYSIS

Four glass chunks and one moil fragment were selected for scientific analysis.¹⁴ 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% Sb_2O_3 , and relatively high levels of lime and alumina, as well as of certain sand-deriving minor and trace oxides (Fig. 6.1).¹⁵ 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.¹⁶ Accordingly, the chunks from the furnace represent a mixed batch consisting of predominantly Sb-decoloured 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 Sb_2O_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,¹⁷ with a certain incorporated amount of manganese, although the antimony oxide content (0.17 wt% Sb_2O_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 assemblages¹⁸ (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.¹⁹ 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 3rd c. AD.²⁰

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.²¹

Cast and blown glass techniques are used for making windowpanes in antiquity.²² 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 3rd c. AD, and most probably they became common during the 4th c. AD.²³ 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 m³, 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 m² 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.

²⁰ IVANOV 2016b.

²¹ PRICE 2005, 172–174; ANTONARAS 2016, 24–25.

²² FOY and FONTAINE 2008; PAYNTER and DUNGWORTH 2011, 22–23.

²³ FOY and FONTAINE 2008, 409–410, 430; ALLEN 2002, 102.

REFERENCES

- ALLEN, Denise, 2002. 'Roman Window Glass'. In: ALDHOUSE-GREEN, Miranda and WEBSTER, Peter (eds.), *Artefacts and Archaeology: Aspects of the Celtic and Roman World*. Cardiff, 102–111.
- ANTONARAS, Anastassios, 2016. *Arts, Crafts and Trades in Ancient and Byzantine Thessaloniki. Archaeological, Literary and Epigraphic Evidence*. Mainz.
- BĂEȘTEAN, Gică and HÖPKEN, Constanze, 2009. 'Ein römischer Wannenofen zum Glasschmelzen in Sarmizegetusa (Rumänien)', *Journal of Glass Studies* 51, 219–223.
- BREMS, Dieter and DEGRYSE, Patrick, 2014. 'Western Mediterranean Sands for Ancient Glass Making'. In: DEGRYSE, Patrick (ed.), *Glass Making in the Greco-Roman World. Results of the ARCHGLASS Project*. Studies in Archaeological Sciences 4. Leuven, 27–49.
- CHERNEVA, Slavka, 2014. 'Stroitelstvoto i zanayatite, svarzani s nego' (The construction work and the related crafts), *Godishnik na regionalniya arheologicheski muzey - Plovdiv (Annual of the Regional Archaeological Museum in Plovdiv)* 12, 258–275.
- CHOLAKOVA, Anastasia, 2008. 'Proizvodstvoto na staklo i stakleni sadove prez kasnata antichnost v balgarskite zemi' (Glass production and glass vessel manufacture during the late Roman Period in Bulgaria). In: GENCHEVA, Evgeniya (ed.). *Studia in honorem Alexandrae Dimitrova-Milcheva. Yugoiztochna Evropa prez antichnostta VI v. pr. Hr. – nachaloto na VII v. sl. Hr. (Southeastern Europe in the Antiquity 6th Century BC – Early 7th Century AD)*. VelikoTarnovo, 471–479.
- CHOLAKOVA, Anastasia, REHREN, Thilo and FREESTONE, Ian, C., 2016. 'Compositional Identification of 6th c. AD Glass from the Lower Danube', *Journal of Archaeological Science: Reports* 7, 625–632.
- DRAZHEVA, Tsonya, 2002. 'Arheologicheski prouchvaniya na kasnoantichna i srednovekovna krepost v m. Gradishteto-Goloe kray s. Lozarevo' (Archaeological researches of the late antique and medieval fortress in Gradishteto-Goloe locality near the village of Lozarevo), *Istoriya i kultura na Karnobatskiya kray (History and Culture of the Karnobat Region)* 4, 171–185.
- DYCZEK, Piotr, 1999. 'A Glass Atelier from Sector IV in Novae'. In: VON BÜLOW, Gerda and MILČEVA, Alexandra (eds.), *Der Limes an der Unteren Donau von Diocletian bis Heraclios*. Sofia, 99–104.
- DZHINGOV, Georgi, 1965. 'Drevnoto staklo i stakloproduktstvo v Bulgaria' (The ancient glass and glassmaking in Bulgaria), *Arheologiya (Archaeology)* 4, 11–20.

- FISCHER, Andreas, 2009. *Vorsicht Glass! Die römischen Glassmanufakturen von Kaiser-augst*. Forschungen in Augst 37. Augst.
- FOLLMANN-SCHULZ, Anna-Barbara, 1991. 'Fours de verrier romains dans la province de Germanie Inferieure'. In: *Ateliers de verriers de l'Antiquité à la période pré-industrielle. Actes des 4emes Rencontres de l'AFAV, Rouen 24–25 novembre 1989*. Rouen, 35–40.
- FOY, Danièle, 2010. 'L'implantation des ateliers de verre en Gaule: centres urbains, péri-urbain et ruraux'. In: CHARDRON-PICAULT, Pascale (ed.), *Aspects de l'artisanat en milieu urbain: Gaule et Occident romain*. Actes du colloque international d'Autun, 20–22 septembre 2007. *Revue archéologique de l'Est* 28. Dijon, 345–361.
- FOY, Danièle and FONTAINE, Souen, 2008. 'Diversité et évolution du vitrage de l'Antiquité et du haut Moyen Age. Un état de la question'. *Gallia* 65, 405–459.
- FOY, Danièle, THIRION-MERLE, Valérie and VICHY, Michèle, 2004. 'Contribution à l'étude des verres antiques décolorés à l'antimoine', *Revue d'Archéométrie* 28, 169–177.
- FREESTONE, Ian C., 2015. 'The recycling and reuse of Roman glass: analytical approaches', *Journal of Glass Studies* 57, 29–40.
- FREESTONE, Ian C., GUTJAHR, Marcus, KUNICKI-GOLDFINGER, Jerzy, McDONALD, Iain and PIKE, Alasdair, 2015. 'Composition, technology and origin of the glass from the workshop at 35 Basinghall Street'. In WARDLE, Angela, *Glassworking on the Margins of Roman London: Excavations at 35 Basinghall Street, City of London, 2005*, Museum of London Archaeology Monograph 70. London, 75–90.
- GENCEVA, Evgenia, 1999. 'La production dans le camp militaire romain Novae pendant la Basse Antiquité (à l'instar du scamnum tribunorum)'. In: VON BÜLOW, Gerda and MILCEVA, Alexandra (eds.), *Der Limes an der Unteren Donau von Diocletian bis Heraclios*. Sofia, 95–96.
- GOMOLKA, Gudrun, 1978. 'Spätantike und frühmittelalterliche Gläser aus dem Limeskastell Iatrus bei Krivina (Bez. Ruse), Nordbulgarien'. In: PHILIPPE, Joseph (ed.), *Annales du 7^e Congrès International d'Étude Historique de Verre. Berlin-Leipzig 15–21 août 1977*. Liège, 25–30.
- GRATUZE, Bernard, 2016. 'Glass characterisation using laser ablation inductively coupled plasma mass spectrometry methods'. In: DUSSUBIEUX, Laure, GOLITKO, Mark and GRATUZE, Bernard (eds.), *Recent Advances in Laser Ablation ICP-MS for Archaeology, (Natural Science in Archaeology)*, Berlin, 179–196.

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

- GRATUZE, Bernard, 2018. 'Contribution à l'étude des verres décolorés à l'antimoine produits entre le I^{er} s. et la fin du III^e s. de notre ère : nouvelles données analytiques'. In FOY, Danièle et al., *Verres incolores de l'Antiquité romaine en Gaule et aux marges de la Gaule*. Volume 2 : *Typologie – Analyses*. Archaeopress Roman Archaeology 42, Oxford, 350–382.
- GUÉRIT, Magalie and GRATUZE, Bernard, 2016. 'Le mobilier en verre de deux ateliers de verriers antiques «Quartier des Prieurs» au Pègue (Drôme): méthodologie et analyses', *Revue archéologique du Loiret et de l'axe ligérien*, hors-série n° 3, 43–49.
- IVANOV, Mario, 2011. 'Rezultati ot arheologicheskite prouchvaniya vav vrazka s izgrazhdaneto na metrostanciya 8-II, Sofiya' (Results of the archaeological excavations during the construction of the 8-II underground station in Sofia), *Pametnitsi, restavratsiya, muzei (Monuments, Restoration, Museums)* 3–4, 3–10.
- IVANOV, Mario, 2013. 'Arheologicheskoto prouchvane na obekt "Metrostanciya 8-II, sektor iztok", gr. Sofiya prez 2012 g.' (Archaeological excavation of the site "Metrostanciya 8-II, east area", in Sofia during 2012), *Arheologicheski otkritiya i razkopki prez 2012 g. (Archaeological Discoveries and Excavations in 2012)*. Sofia, 290–292.
- IVANOV, Mario, 2016a. 'Two Early Christian Basilicas in Serdica: New Archaeological Data'. In: BRANDT, Olof, FIOCCHI NICOLAI, Vincenzo and CASTIGLIA, Gabriele (eds.), *Acta XVI Congressus Internationalis Archaeologiae Christianae. Romae 22–28. 9. 2013*. Studi di Antichita Cristiana 66. Citta del Vaticano, 394–404.
- IVANOV, Mario, 2016b. 'Herma s nadpisi ot Serdica' (A herm with inscriptions from Serdica), *Arheologiya (Archaeology)* 1–2, 67–72.
- JACKSON, Caroline, 2005. 'Making colourless glass in the Roman period', *Archaeometry* 47, 763–780.
- JACKSON, Caroline and PAYNTER, Sarah, 2015. 'A great big melting pot: exploring patterns of glass supply, consumption and recycling in Roman Coppergate, York', *Archaeometry* 58, 68–95.
- KABAKČIEVA, Gergana, 1987. 'Produzione vetraria di Oescus. Note preliminari', *Ratiarensia* 3–4, 171–176.
- KOVACHEVA, Teodora, 1996. 'Kam vaprosa za datirovkata na staklarskata rabotilnitsa v Eskus pri s. Gigen, Loveshka oblast' (About the date of the glass workshop in Oescus near the village of Gigen, Lovech district), *Izvestiya na muzeite ot Severozapadna Bulgaria (Bulletin of the Museums of Northwestern Bulgaria)* 24, 33–42.
- KOYCHEVA, Kina, 1990. 'Rannovizantiyska staklarska rabotilnica' (Early Byzantine glass workshop), *Arheologiya (Archaeology)* 4, 36–46.

- LELJAK, Mia and LAZAR, Irena, 2013. 'Roman Glass Workshops in the Croatian Part of the Province of Pannonia', *Vjesnik arheološkog muzeja u Zagrebu* XLVI, 3, 115–133.
- LEPRI, Barbara and SAGUI, Lucia, 2017. 'Mapping Glass Production in Italy. Looking through the First Millennium AD'. In: WOLF, Sophie and DE PURY-GYSEL, Anne (eds.), *Annales du 20^e congrès de l'Association internationale pour l'histoire du verre, Fribourg-Romont 7-11 septembre 2015*. Romont, 168–174.
- NENNA, Marie-Dominique, 2008. 'Nouveaux acquis sur la production et le commerce du verre antique entre Orient et Occident', *Zeitschrift für schweizerische Archäologie und Kunstgeschichte* 65, 61–66.
- OLCZAK, Jerzy, 1998. *Produkcja szkła rzymskim i wczesnobizantyjskim Novae*. Toruń.
- PAYNTER, Sarah and DUNGWORTH, David, 2011. *Archaeological Evidence for Glass-working. Guidelines for Best Practice*. English Heritage Publishing.
- PAYNTER, Sarah and JACKSON, Caroline, 2016. 'Re-used Roman rubbish: a thousand years of recycling glass', *European Journal of Postclassical Archaeologies* 6, 31–52.
- PAYNTER, Sarah and JACKSON, Caroline, 2019. 'Clarity and Brilliance: antimony in colourless natron glass explored using Roman glass found in Britain', *Archaeological and Anthropological Sciences* 11, 1533–1551
- POPOVA, Vania, 2017. 'Late Antique Glass Workshop in Parthicopolis'. In: NANKOV, Emil (ed.), *Sandanski and its Territory during Prehistory, Antiquity and Middle Ages. Current Trends in Archaeological Research. Proceedings of an International Conference at Sandanski, September 17-20, 2015*. Papers of the American Research Center in Sofia 3. VelikoTarnovo, 267–284.
- PRICE, Jennifer, 2005. 'Glass-working and glassworkers in cities and towns'. In: MacMAHON, Ardle and PRICE, Jennifer. *Roman Working Lives and Urban Living*. Oxford, 167–190.
- REHREN, Thilo and PERINI, Elisa, 2005. 'The glass furnace debris'. In: SEELEY, Fiona and DRUMMOND-MURRAY, James. *Roman Pottery Production in the Walbrook Valley. Excavations at 20–28 Moorgate, City of London, 1998–2000*. Museum of London Archaeological Service Monograph 25. London, 184–186.
- SEBASTIANI, Alessandro and DERRICK, Thomas J., 2016. 'The Glass Workshops and Glass Assemblage from Spolverino (Alberese - GR)', *Journal of Glass Studies* 58, 279–286.
- SCHIBILLE, Nadine, STERRETT-KRAUSE, Allison and FREESTONE, Ian C., 2017. 'Glass groups, glass supply and recycling in late Roman Carthage', *Archaeological and Anthropological Sciences* 9, 1223–1241.

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

STAWIARSKA, Teresa, 2014. *Roman and Early Byzantine Glass from Romania and Northern Bulgaria. Archaeological and Technological Study*. Warsaw.

TORBATOV, Sergey, MANOLOVA-VOYKOVA, Maria, IVANOVA, Bilyana and KARABASHEV, Anton, 2015. ‘Spasitelno arheologichesko prouchvane na UPI I, kv. 122, gr. Pomorie’ (Rescue excavations in Plot I, Square 122 under the plan of Pomorie), *Arheologicheski otkritiya i razkopki prez 2014 g. (Archaeological Discoveries and Excavations in 2014)*. Sofia, 308–310.

TRAK, Zhorzh and CHERNEVA, Slavka, 2011. *Stakloto v antichnoto izkustvo (The glass in the Art of Antiquity)*. Plovdiv.

TRISTE, Alain and DARE, Sébastien, 2005. *L’atelier de verriers antiques de Kerfloc’h 2, commune de Plaudren (Morbihan). Rapport de sondage archéologique*. Service Régional de l’Archéologie de Bretagne-Rennes.

VAGALINSKI, Lyudmil, 2017. ‘Heraclea Sintica’, *Arheologicheski otkritiya i razkopki prez 2016 g. (Archaeological Discoveries and Excavations in 2016)*. Sofia, 301–304.

MARIO IVANOV

National Institute of Archaeology with Museum
Bulgarian Academy of Sciences
2, Saborna Str.
1000 Sofia, Bulgaria
slotarm74@gmail.com

ANASTASIA CHOLAKOVA

National Institute of Archaeology with Museum
Bulgarian Academy of Sciences
2, Saborna Str.
1000 Sofia, Bulgaria
sia_cholakova@hotmail.com

BERNARD GRATUZE

IRAMAT – Centre Ernest Babelon (UMR 5060)
CNRS – Université d’Orléans
Orléans, France
gratuze@cnrs-orleans.fr