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ANNALES

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

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efe glass

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du 21e CONGRÈS de l'ASSOCIATION INTERNATIONALE
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Cover image: Roman handle applique found in the Marmaray-Metro Excavations - Istanbul. 4th Century

in memoriam
YOKO SHINDO

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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)

ABSTRACT

Despite many well-known indications suggesting the presence of a flourishing glass production in Aquileia during the Roman age, to date no furnace has ever been identified. In November 2017, during field-walking survey activities part of the EC funded landscape archaeology project Visualising Engineered Landscape (VEiL), an extraordinary concentration of hundreds of raw glass chunks and shards of glass was identified on the surface of a ploughed field in the Northern fringes of the Roman city, just outside the ancient city walls. Fragments collected included several chunks encrusted on refractory material (the majority being natural blue-green, with smaller quantities in blue and olive green), droplets and trails together with other glass working wastes and fragments of vessels. This remarkable in situ plough soil assemblage, clustered in a relatively small spatial dispersion, may reflect the existence of a secondary glass workshop. This paper expands on the satellite imagery analysis and the field prospections that led to the identification of the archaeological context and the preliminary outcomes provided by morphological and archaeometric analysis including Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) and UV-Vis Reflectance Spectroscopy carried out on some of the most relevant samples of glass recovered. This new discovery could represent a unique opportunity to expand our current understanding of use and consumption of glass in Roman period in the area and the broader northern Adriatic context.

1. INTRODUCTION

Located at the head of the Adriatic Sea (Fig. 1), Aquileia, the Roman city in NE Italy founded in 181 BC, is referred by ancient

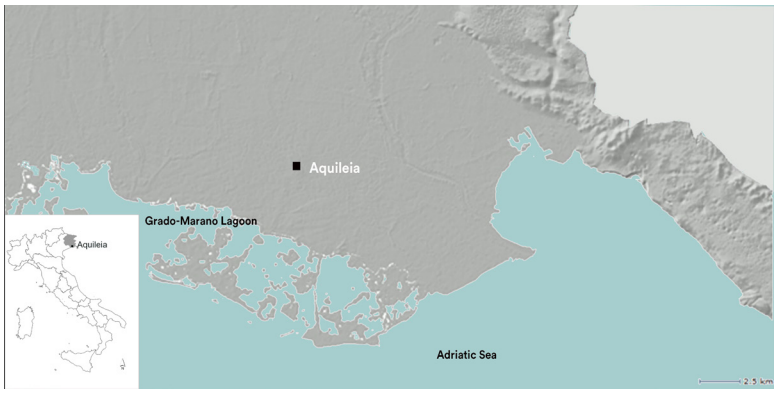

Fig. 1: Location of Aquileia in the regional and national context. © Arianna Traviglia.

sources as an important commercial *emporium* and one of the most important urban centres of the late Roman Empire.[1] Thanks to an integrated network of roads and natural and artificial waterways, forming an efficient interconnected system, the city progressively became a key trade node between the Eastern Mediterranean, the Danube area, the Balkans, and the Northern part of Italy, reaching its peak in the 4th century AD.

Archaeological investigations in the past century have largely demonstrated the relevant role played by the city in the economy of the Empire as a production centre of pottery (e.g. lamps and tiles production) and a venue for ironworking and amber carving.[2] Many indicators also suggest the existence of a flourishing glass production in Aquileia. Two varieties of stamps, appearing on the bottom of two bottles found in Linz[3] and on a fragment recently discovered in Slovenia,[4] mention *Sentia Secunda* as a glassmaker working in Aquileia, potentially pointing out the existence of glass workshops in Aquileia. Epigraphic evidence is supported by the recovery of great abundance of glass shards and a relevant number of possible glass crucible and glass-working waste both in archaeological excavations and plough topsoil all over the Aquileian urban and suburban territory.[5] A (likely) small workshop, recycling blue mosaic glass tesserae, has been recently identified in the late imperial levels of a large mansion in the Northern part of the Roman city: it represents the first stratigraphically excavated evidence of coloured glass re-working at Aquileia.[6]

Notwithstanding these abundant indications, no workshops directly connected with glass melting or glass blowing have ever been identified so far in Aquileia, thus hindering the hypotheses relative to Aquileia as a Mediterranean-level glass workingnode formulated in the past 80 years or so.[7] Archaeometric approaches, aiming to use compositional analysis to test glass fragments from the Aquileian territory and compare obtained data with other datasets from literature, might therefore be decisive to understand if Aquileia played simply a main role in glass consumption and supply during antiquity, or instead hosted important secondary workshops using either imported raw glass from primary workshops or recycled glass.

2. A POTENTIAL NEW SITE FOR GLASS MAKING

New potential indications of a glass production in Aquileia emerged in November

1 Aus., Ordo urb. Nob. 65; Aus., Ordo urb. Nob. 67.
2 BOSCHETTI et al. 2016. For further bibliography see ZACCARIA 2007.
3 NOLL 1949, 27–28, figs. 72 (G 99a) and 73 (G 99c).
4 LAZAR 2005, 41-42.
5 For a detailed review see BUORA et al. 2009; BUORA AND MORETTI 2013.
6 BOSCHETTI et al. 2016.
7 BUORA et al. 2009.

2017 during the field-walking surveys activities carried out within the H2020-funded landscape archaeology project VEiL (Visualizing Engineered Landscapes), focused on investigating engineered landscapes around Roman Aquileia.[8]

Spreads of potential archaeological artefacts on plough soil in an area located in the NE Roman *suburbium* of Aquileia were first identified on remote sensing imagery: upon detection, the spots were surveyed on the ground to validate the discovery, while legacy data research was completed at the same time to gain background information.

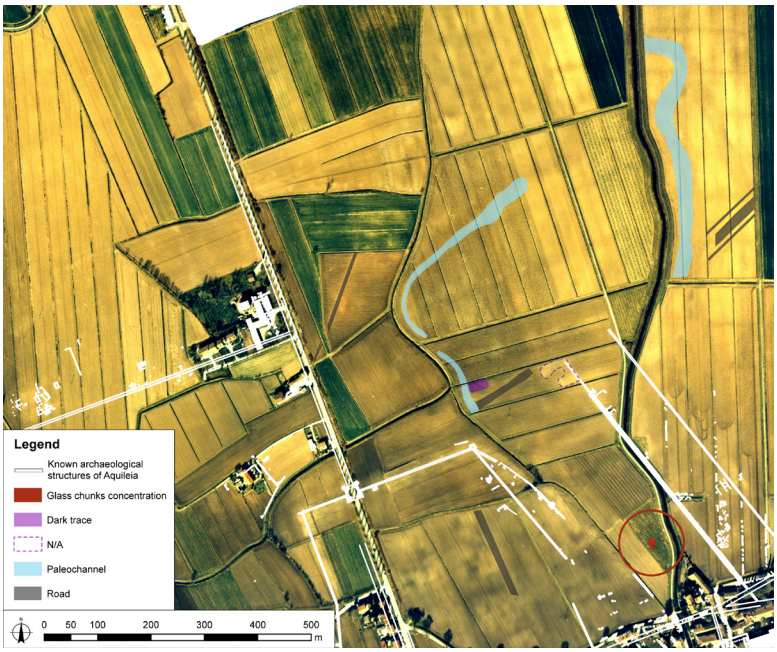

Fig. 2: Aerial photo displaying mapped features relative to: i) the identified site, ii) traces from aerial photo-interpretation, and iii) known archaeological structures of Aquileia (base layer: orthophoto, © CGR Spa Parma and Region Friuli Venezia Giulia[9].)

2.1. *Legacy archaeological data*

The NE *suburbium* of Aquileia is indicated by multiple sources (archive data, historical maps, archaeological evidence, remote sensing) as a venue for roads, graves and villas built during the Roman period. The area likely played a relevant role in the life of the ancient city, being crossed by important secondary roads acting as connections between the main roads directed to the North (Via Julia Augusta), North-East (Via Gemina) and West (Via Annia).[9] An ancient cobbled road, used as shortcut to avoid the traffic affecting the city centre, was discovered here in 1885, during excavations carried out by Eugen Ritter von Záhony on his own property and re-buried afterwards[10]. its trace, visible in remote sensing imagery, corresponds to the most western of two parallel roads detected in the aerial imagery used in this project (see below). In the same occasion two graves emerged beside the E edge of this road. A third grave was discovered in the same area, but the circumstances of its recovery are unknown.[11] Archive research pointed out further findings N of the investigated area, including several inscriptions discovered in the 19th century.[12] Not far from the area, a number of production buildings were also discovered including a workshop with elements suggesting the onsite re-use of blue mosaic glass tesserae,[13] a kiln for bricks, tiles, and floor covering,[14] a workshop pro-

8 TRAVIGLIA AND TORSELLO 2018.
9 MAGGI AND ORIOLO 2004.
10 GIOVANNINI 2015.
11 GIOVANNINI 2015.
12 For a detailed review see REBAUDO 2013.
13 BOSCHETTI et al 2016.
14 BUORA AND MAGNANI 2011.

ducing lamps[15] and a building organised around a court.[16]

2.2. *Remote sensing identification*

The VEiL project case study areas consist mainly of agricultural fields, a circumstance that enables to exploit at its best remote sensing approaches to detect and map marks and anomalies on bare soils or crops that could be generated either by the existence of underground ancient structures (such as roads and other evidences of ancient occupation) or palaeo-hydrography.

Imagery used in this research spans from aerial photographs (both historical and more recent orthophotos) to satellite imagery from Sentinel and hyperspectral data from MIVIS sensor. All the analysed images have been treated to increase contrast and sharpness and further processed, in order to enhance the visibility of specific features present on the ground.[17]

An area of interest was identified in some of the analysed images in a locality referred as 'Paludetti', just outside the ancient city walls, at the NE fringes of the ancient city, in an area corresponding to the SE part of the cadastral parcel no. 397/1, nowadays an agricultural field that was spared by the 20th century urbanisation. The feature appears both in images shot when crops are at their maximum growth and in those shot after ploughing (therefore displaying bare soils) as a triangular shaped trace on the ground, and it was interpreted as a concentration of fragments of archaeological materials lying on the top soil (Fig. 2).

Visual inspection of the processed imagery clearly revealed also in this area the traces of the ancient Northern walls of the city and the city gate, partially excavated in the past and now re-buried. Two parallel roads are also visible E of the city walls and another one N of the city walls. The complexity of the hydrographic system surrounding Aquileia[18] is further suggested by a bend of a palaeo-riverbed N the city walls, which appears quite clearly in several of the images.

2.3. *Ground truthing*

The remote-sensing identification of this potential archaeological site prompted to undertake ground-truthing activities on the area to verify the consistency of the archaeological deposit. An extraordinary concentration of glass chunks and glass shards was thus easily identified on the topsoil of the ploughed field in the location indicated by the images. Most of the fragments were recovered in quite a limited area (measuring about 15-20 m of length by 10-15 m of width – Fig. 3).

Fragments collected included 459 glass chunks and 53 glass working wastes including droplets and trails, these being just a part of what was available on the ground which could not be fully collected (Fig. 4). Many of the chunks (the biggest of which measures 7 x 4,5 x 2,3 cm) - the majority being deep blue-green, with smaller quantities in blue and olive green - were encrusted with spurious material. Elemental analysis of the superficial crust of one chunk performed through EDS indicates that its composition resemb- les that of ancient Roman mortar. A high number of glass artefacts fragments has been recovered in association with the

15 DI FILIPPO BALESTRAZZI 1987.
16 BUORA 2017.
17 TRAVIGLIA 2011.
18 See also BUORA AND MAGNANI 2011.

Fig. 3: The field-walking survey area (left); 1x1m sampled unit (middle); chunks recovered on the plough soil (right) © Arianna Traviglia.

chunks, including glass shards (271), potsherds (590 fragments), and 145 fragments of other classes of materials. Most glass shards date back to the 1st-2nd century AD (with abundance of bowls types Isings 3, Isings 42 and Isings 44), but mid– and late imperial period forms are also present in smaller quantities (Isings 85 bowls, goblet Isings 111), suggesting a more sporadic late-imperial period attendance of the area. The other classes of materials found in association with the glass reflect a similar chronological pattern.

To date no coring, geophysical prospections or excavation data is available, but the type of recovered finds and their concentration in a relatively small area seem to suggest the presence of the remains of a glass workshop in the subsoil of the field, probably amounting to only the foundation levels. The closeness and abundance of glass chunks might also indicate that the stratigraphic unit in which they were included could have been just recently eroded by the plough and its inclusions taken up to the surface: the dispersion pattern of the artefacts testifies this hypothesis, with the chunks spread within quite defined boundaries within a limited area, which is not compatible with a long exposition of the fragments within the topsoil. Visual inspection, moreover, does not show the presence of scratches and breakages that are instead typical of fragments that have been often reshuffled by plough works. Samples of fragments collected were turned over to the lab archaeometric analysis in order to infer the nature of the glass chunks (specifically, if they were chunks of primary or secondary glass), to relate them to the glass artefact fragments found in association and to identify any further markers indicating the presence of a buried furnace.

3. PHYSICOCHEMICAL CHARACTERISATION

The composition of glass samples can be obtained by elemental analysis that measures the concentration of major and minor -and sometimes trace- elements, depending on the used analytical technique. Elemental analysis enables to characterise raw materials (sands and fluxes), decolourisers, chromophores and opacifiers as well as the mineral sources (i.e. of cobalt or copper). As such, it can indicate the primary and/or secondary nature of the chunks and the production period of the analysed samples through the comparison of the obtained data with other datasets from literature.

Physicochemical characterisation was performed on the recovered finds to recognise whether the glass chunks were from pri-

Fig. 4: Glass chunks and artefacts recovered on the site ©Arianna Traviglia.

mary glass kilns (through bivariate and multivariate statistical analysis of the elements related to the raw materials) or secondary glass production from the fusion of recycled glass (mainly through the levels of the antimony and manganese-based decolourisers). Glass recycling was a common practice in antiquity, widely employed to produce both new artefacts or glass ingots to be sold as raw glass to other workshops, either in Aquileia or elsewhere.[19]

3.1. *Materials and methods*

The investigations were undertaken by LA-ICP-MS using a 193 nm ArF* excimer laser ablation system (CetacAnalyte G2, Teledyne CETAC Technologies, Omaha, USA) interfaced with a quadruple ICP-MS (Agilent 7900, Agilent Technologies, Santa Clara, USA) to quantify elements present in the glass samples by laser beam drilling. The mass spectrometer was set up in time-resolved analysis mode, measuring one point per mass and acquiring 55 masses. The morphology of the samples was investigated by Scanning Electron Microscopy (SEM) The morphology of the samples was. These analyses were performed using a TM3000 Hitachi tabletop scanning electrode microscope. The most representative colours of the samples were characterised by Reflectance spect- ra in the UV-Vis wavelength range 360 – 740 nm, performed with a Konica-Minolta spectrophotometer CM-2600d.

3.2. *Results of archaeometric analyses*

Kubelka-Munk UV-Vis Reflectance spectra of the glass samples (Fig.5) allowed the identification of the chromophores and highlight the role of some transition metal ions: copper (Co^{2+} ion with a peak at 785 nm), together with a a small amount of cobalt, for aquamarine blue; manganese (Mn^{3+}, peak at 490 nm) for purple; cobalt (Co^{2+}, three peaks at 535, 595 and 640 nm) for deep blue; iron for yellow-green and blue-green (Fe^{3+} with a main peak at 420 nm for light yellow and Fe^{2+}, that shows the queue of an intense peak at 1150 nm, for light blue) and the complex of iron, sulphur and oxygen ($Fe^{3+}S^{2-}3O^{2-}$) for amber yellow. In the analysed samples, all the chromophores that normally characterise the ancient transparent glass were found.

Preliminary LA-ICP-MS results provided the compositional frame of the samples. This enabled to define the relationships amongst the three type of fragments investigated (glass chunks, artefacts and waste), as well as the comparison with a wide number of Roman glass samples from North East-

19 SILVESTRI 2008.

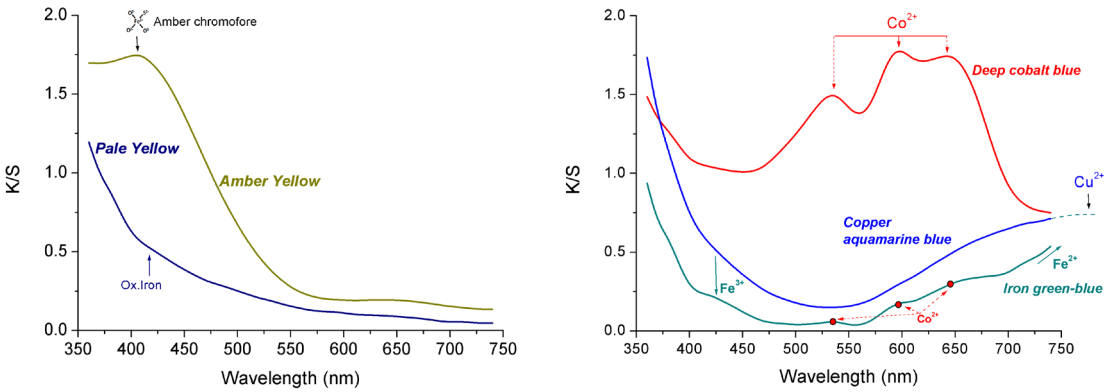

Fig. 5: Kubelka-Munk Reflectance (K/S) spectra of an amber and a pale yellow glass samples (left) and blue and green-blue samples (right). The red points on the latter (right) evidence the presence of traces of cobalt ©Emilio Orsega.

ern Italy (1st to 3rd century AD) and with the types of glass coming from Middle East and Egypt (first half millennium AD).[20] Most of the samples showed compositional features typical of Roman glass objects found in North-Western Europe, dated from 1st to 3rd century AD and of uncertain origin.[21]

The data were first elaborated by bivariate and multivariate analysis considering the elements related to the raw materials. Aluminium, calcium, manganese, iron, titanium, strontium and zirconium were evaluated for the characterisation of sands, while sodium, potassium, magnesium and phosphorous for fluxes. Most of the samples fall in a well-defined cluster that reflects the compositional characteristics of the early Roman Empire glass from the Syrio-Palestinian coast. A small quantity of samples displays features more typical of glasses from the 4th century AD onwards and were produced in a different area of the Middle-East and Egypt.[22]

For most of the samples no statistical evidence of compositional differences was observed among chunks, artefacts and waste samples. These results suggest the common origin of the three types of fragments studied. The analysis of manganese and antimony levels seems to indicate that amost of the samples were made of recycled glass.[23]

The interpretations hereby presented are the result of a preliminary analysis of experimental data. Further investigations are in progress on another set of samples from the same archaeological site. SEM-EDS analysis will be conducted also on a couple of small metal spheres incorporated in two glass chunks to clarify their nature and composition with the goal of understanding the reasons for their presence inside the chunks.

CONCLUSIONS

Preliminary results of the combined morphological and quantitative elemental analyses indicate the Middle East area as the most probable provenience for the majority of the samples examined in this work. The strong chemical similarities between chunk

20 NENNA et al. 1997; FOY et al. 2000; FREESTONE et al. 2000; GALLO et al. 2014.
21 FREESTONE 2003
22 NENNA et al. 1997; FOY et al. 2000; FREESTONE et al. 2000.
23 JACKSON 2005; GALLO et al. 2014; FREESTONE 2015.

and artefact fragments suggest that many artefacts could have been locally produced. Instead, no final conclusions have yet been made about whether the chunks were formed by primary or secondary glass. Ongoing analysis on the mortar encrusting the chunks and some wastes will likely reveal more about the possible nature of the assemblage and of the site, i.e. if the spread of materials on the topsoil reflects the existence of a furnace *in situ*. Future research will concentrate further on chemical data analysis and on the study of other materials found in association with the glass finds to enrich our understanding of the archaeological nature of the site and, possibly, of the provenance of the glass finds.

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