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Archaeometric Notes

Glass finds from Banbhore: An Archaeological and Archaeo-metric Approaches for the Study of the Assemblages (Preliminary Report)

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PhD in History Cultures and Civilizations, Tania Chinni is an archaeologist glass specialist in the study and recognition of artefacts datable to the Middle Ages. She has participated in several Italian and international archaeological surveys and published in several scientific international journals. She collaborated on the ministerial project PRIN 2009 ***Continuity and discontinuity in High-Adriatic glass production between the 9th century BC and 15th century AD*** *(Universities of Bologna and Padua). She was tutor for the Single Cycle Degree Course in "Conservation and Restoration of Cultural Heritage" of the University of Bologna (Campus of Ravenna) (2016/2017, 2017/2018). Currently she collaborates with the Conservation Science Laboratory for Cultural Heritage and she is the leader of the Italo-Armenian Project* ***ROCHEMP: Regional Office for Cultural Heritage Enhancement Management and Protection.***

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PhD in Applied Physics to Cultural Heritage, Sara Fiorentino is a Conservation Scientist specialised in Archaeometry. Since 2012 she has been collaborating on study and consultancy activities related to the field of applied Conservation Science, with specific interest in the study of production technologies and the conservation issues of archaeological artefacts and historical building materials. Co-author of several publications in indexed scientific journals, she has participated as a speaker at national and international conferences. Teaching assistant for the Integrated Course in Chemistry and Conservation of Materials at the School of Arts, Humanities and Cultural Heritage of the University of Bologna, lectures and assistance to laboratory activities for students.

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After an initial period of scientific activity in the field of semiconductor materials for electronics, since 1997 she has been carrying out research on scientific methodologies for the study of cultural heritage. In particular, through archaeometric analysis and investigations on materials of archaeological and historical-artistic interest, the research is aimed at characterising raw materials and production technologies, as well as to provide data and evaluation of the state of conservation of the artworks and finds, investigating the causes of deterioration through the characterisation of degradation phenomena. Since 2000-2001 she is teaching at the Faculty of Conservation of Cultural Heritage, now School of Letters and Cultural Heritage, in Specialisation Schools, in master's and in Doctoral Schools of Alma Mater Studiorum University of Bologna, as well as in numerous training courses. She published extensively her research in highly recognized international scientific journals and book.

Abstract:

An assemblage of glass finds from the Banbhore excavation was selected for preliminary recognition according to well-established and scientific-based methodological approach. The available set, consisting of 173 fragments recovered from three trenches (nos. 7, 8 and 9), was preliminarily observed by naked eye and recorded, distinguishing, where possible, between diagnostic elements (hems, bottoms and loops) and wall fragments. After a preliminary cleaning of surface deposits, the archaeological study of the finds was carried out by means of a preliminary grouping of the original typologies in macro-categories, followed by the use of non-invasive methods for an objective documentation and description of the colour. Following these preliminary operations, the glassware fragments will undergo an integrated, multi-methodological research approach. First, chrono-typological study will provide, through a detailed comparison with published catalogues of assemblages from similar context, suitable data to put the recognisable forms into proper contextualisation, taking into consideration the

provenance site and its peculiarities. The archaeological study of the fragments will, thus, be fundamental for the following analytical phases, that will allow to frame compositional features and raw materials used in the manufacture of glasses from Banbhore within ancient glass manufacturing, in the perspective of identifying possible technological and/or compositional connections with Middle Eastern and Eastern areas.

Keywords: *Ancient glass, Trade, Production, Archaeology, Archaeometry*

Introduction

The assemblage of glass finds from the Banbhore excavation delivered to the Diagnostic Laboratory for Cultural Heritage (Department of Cultural Heritage, University of Bologna – Ravenna campus) consists of 173 fragments, recovered from Trench 7 (n. 30 fragments), Trench 8 (n. 17 fragments) and Trench 9 (n. 126 fragments).

1. Archaeological study: methodology applied

The glass finds were delivered in airtight bags with identification records of the original layer, stored inside a properly sealed rigid plastic container to preserve their integrity during transport.

According to the practice adopted at the aforementioned Laboratory, the assembly was, first, subjected to a preliminary naked-eye study of the fragments, to verify their conditions of integrity and stability. During this procedure, the fragments were extracted from their original packages, cleaned from surface earth debris (without removing alteration layers), organised and recorded in a database and sealed again in clean airtight packages.

The cleaning operations were carried out without the use of water or any solvent, in order to avoid alteration to the state of conservation of the fragments. The removal of surface deposits was performed mechanically, using a soft-bristle toothbrush and, occasionally, dental tools to test the consistency of the larger deposits. The cleaning was delicate and without insisting on the most consistent deposits, in order to avoid further fragmentations.

Preliminary recording was made at the same time as cleaning, leading to the collection of all the identifying elements of the context of origin, a general description of the individual fragments and their state of preservation, macroscopic description of the colour and, where possible, indication of the functional category of the original object (beaker, bottle, cup, bracelet, slag). This recording operation has the dual function of allowing a preliminary counting of the fragments, distinguishing between those suitable for recognizing the original form of the object (rim, bottom, handle) from those that can hardly be associated with objects (in particular walls, especially if lacking of any decoration), and to allow a first general assessment of the set of finds.

Specific attention was payed to the evaluation of colour: it was, first, macroscopically checked, distinguishing the fragments in larger chromatic groups (blue, green, colourless, etc.); then, using the Natural Colour System (NCS), a more objective classification of chromatic shades was achieved **(Figure 1)**. This method, which requires the use of colour comparison cards, allows to assign a code to the colour registered by the operator, with the advantage to go beyond the subjectivity limits that often afflict a punctual determination of the colour (https://ncscolour.com/).

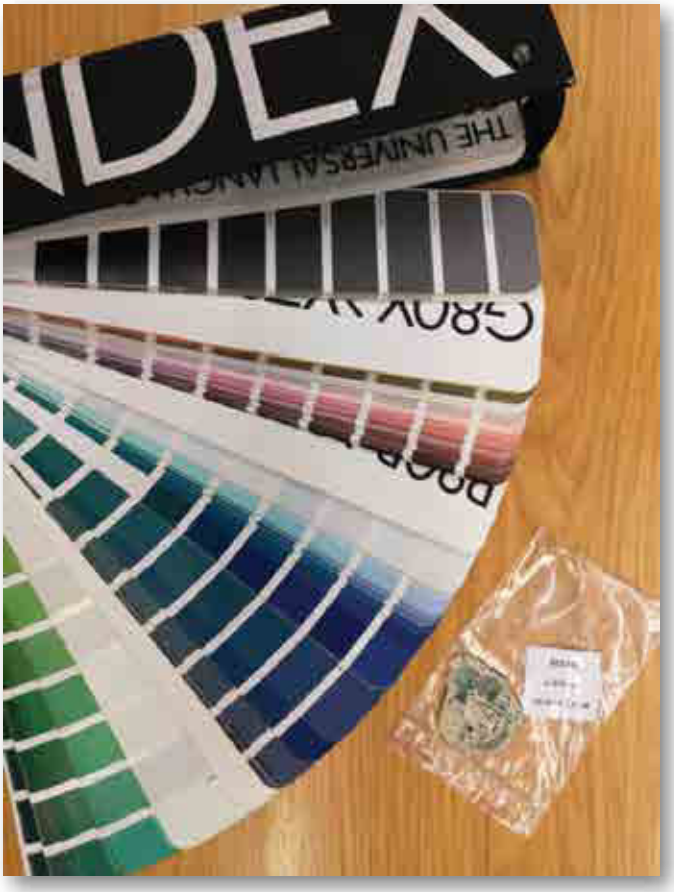

Figure 1. *Comparison of samples with NCS Chart for an objective definition of the chromatic shade.*

2. Glass assemblage: general description

This preliminary observation allowed attesting that the assemblage under study shows a high degree of fragmentation, with medium-sized finds. This situation generally affects all archaeological contexts with continuity of occupation, as the objects were reused several times and discarded only if seriously damaged. The fragments identified during the preliminary operations can be mostly related to tableware, like beakers and medium-size cups. Sporadic fragments referable to small containers have also been identified,

for the storage of balsams or other perfumed substance; some thin glass filaments, referable to small bracelets, have also been found. Some fragments of undefined and rounded shape could be ascribed to glass slags; however, in the absence of specific data concerning the presence of furnaces, the existence of a possible local production is considered unlikely.

The majority of the fragments shows unstable conditions, with evident and extensive alterations clearly attributable to the burial conditions. These alterations often completely cover the fragments, preventing an exact evaluation of their colour. In some cases, a general assessment of the colour can be observed in section, where, however, the colour tends to be more intense. It was also noticed that the occurrence of whitish or brownish alterations affects almost all tableware fragments, but not the bracelets.

3. Glass studies: next steps

The next step will consist in the assessment of a more detailed documentation of the fragments under study. The finds selected as functional and informative for the recognition of a form or category will be programmed in a database, with descriptions, dimensions and drawings on an appropriate scale. For this purpose, the adopted procedure will be in line with well-established archaeological procedure, following appropriate criteria for the evaluation of dimensions and profiles for an exact and precise reproduction of fragments.

Where necessary, photographic documentation will also be performed with appropriate metric and colour scales for the digital correction of tonal deviations, especially to record details of peculiar elements detected on the finds. The precise cataloguing of the fragments and the graphic documentation produced will be fundamental for the typological study, which will take place through direct comparison of the produced documentation with available literature, selected by area and chronological framework.

4. Archaeometric study: proposed analytical approach

Following chrono-typological study, archaeometric analyses will be carried out on carefully selected samples among the available assemblage of fragments.

In accordance with the established procedure at the Diagnostic Laboratory for Cultural Heritage, the definition of the analytical protocol will be aimed at integrating and completing data achieved through previous chrono-typological study of the finds, granting a strong trans-disciplinary approach distinguishable in the dialogue between archaeological and archaeometric data.

Analyses will be aimed at determining compositional features of the glass, providing information on raw materials used as vitrifying, fluxing and, eventually, stabilising agents. For coloured fragments, analysis of colouring agents and materials for obtaining the different chromatic shades will also be carried out, to gain information on related technological issues. The proposed analytical methods can be summarised as follows:

• **Optical Microscopy (OM):** An Olympus S761 stereomicroscope (magnification up to ×45) associated with an Olympus Soft Imaging Solutions GMBH model SC100 camera will be used for a preliminary morphological observations and documentation of selected fragments, as well as to document the eventual occurrence of surface degradation morphologies **(Figure 2)**.

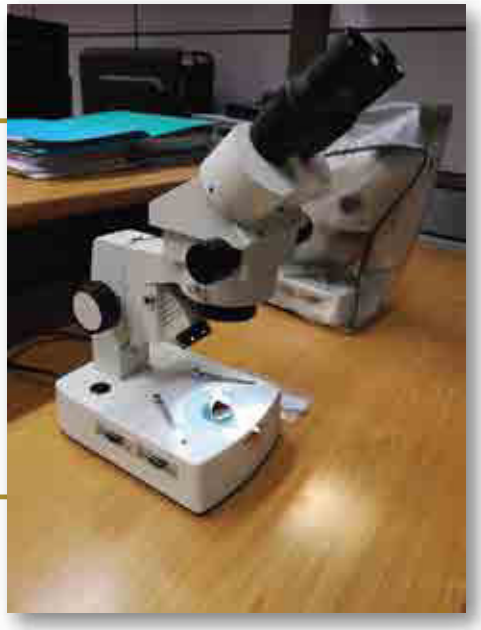

Figure 2. *Example of vessel's fragment observation under optical microscope.*

• **Sampling and preparing:** Micrometric samples will be taken from the fragments, in order to prepare cross-section for laboratory analyses. Sampling will be conducted under optical microscope, paying attention to sampling areas not compromising the integrity of the fragment. Polished sections will be prepared by embedding micro-samples in a polyester resin.

• **Scanning Electron Microscopy (SEM):** Performed on polished cross-sections, SEM analyses will allow high-resolution textural and morphological inspection of the glassy matrix, detecting the eventual presence of inclusions ascribable to either raw materials or precipitated phases. Back-scattered electron signal (BSE) will be acquired for the inspection of the morphological features of the glassy matrix, coupled with EDS measurements to achieve a preliminary qualitative and semi-quantitative elemental analysis.

Images and EDS spectra will be collected on a low-vacuum ESEM FEI Quanta 200, equipped with an EDAX energy dispersive spectrometer **(Figure 3)**. Analyses will be performed in high-vacuum, using an acceleration voltage of 25kV and an energy resolution of

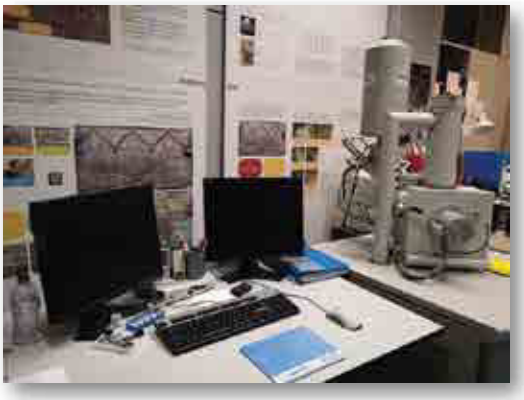

Figure 3. *SEM-EDS facility available at the Department of Cultural Heritage, University of Bologna.*

~ 200 eV; working distance will be set at 10 mm, spot size was between 4 and 5 µm.

• **Electron Probe Micro-Analysis (EPMA) and Laser Ablation fixed with Inductively Coupled Plasma Mass Spectrometry (LA–ICP–MS):** To be performed on cross-sectioned micro-samples in order to determine the bulk composition of the glass, measuring major, minor and trace elements. As these instrumental facilities are not available at the Diagnostic Laboratory for Cultural Heritage, these analyses will require collaboration with other laboratories, with which our staff has successfully collaborated in the past.

The analytical protocol may be susceptible to work in progress changes, which could be necessary both for the types of samples under study and for the data gradually obtained and processed. The necessity of performing further investigations with facilities available at the Diagnostic Laboratory (like diffrattometric[1] or spectroscopic[2] analyses) will also be taken into consideration.

One the analyses will have been completed, data obtained from this study will be contextualised in the available and updated literature on the topic, with the prime aim of highlighting analogies and differences with previously studied assemblages of glass finds from other sites, to draw inferences upon the existence of eventual relationships.

1, XRPD analyses will be performed on finely powdered samples, manually pressed on an Ag sample holder in a Rigaku Miniflex diffractometer employing CuKα1 radiation, in the range 2Θ: 4°-64°, Θ scan speed: 1°min-1.
2. i.e. Raman Microscopy measurements, by using a Bruker Senterra dispersive Raman spectrometer equipped with an integrated Olympus BX40 microscope. A 785 nm He-Ne laser will be employed, in the 300-3500 cm-1 region. Analytical measurements will performed with a 25X or 50X long working distance objective, operating at a power between 1 and 10 mW with a spectral resolution of 3.5 cm-1.