The study of Byzantine Glass Mosaic Tesserae from Albania using Nuclear Techniques

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Introduction

Results of an archaeometric investigation performed on several glass mosaic tesserae from Early Christian basilicas in Albania are presented.

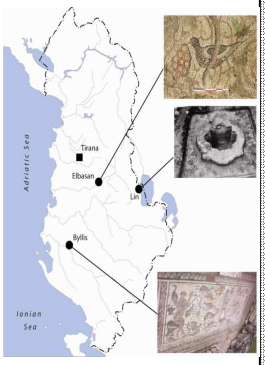
The three archeological sites under investigation are situated in Byllis, Lin and Elbasan and belong to V - VI century AD.

The basilicas' floors are decorated with colorful mosaics with geometric and floral motifs and scenes from everyday life [1, 2, 3].

The elemental composition of glass and its microstructure reflects the raw materials and the techniques that were employed in its manufacture.

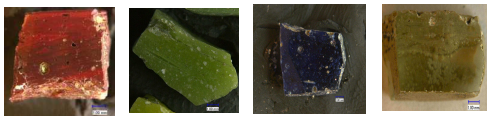
A multi analytical approach, which includes optical microscopy, scanning electron microscopy equipped with energy-dispersive spectrometer (SEM-EDS), micro X-ray fluorescence and Raman spectroscopy, are used during the investigation.

The main objective of the study is the characterization of the type of materials, glass matrix, coloring and opacifying agents used for their production as well as the investigation of the micro-structures of opaque coloured glass mosaics tesserae.



Materials and methods

For this work a total of 71 glass tesserae, coming from excavations in Lin, Byllis and Elbasan and dating between the end of Vth and beginning of VIth century AD, were analyzed. The glass tesserae had different colour and dimensions smaller than 1 cm x 1cm.



Archaeological sites	Nr. of tesserae/Nr. of colours
Byllis	11 tessera/7 diferent colours
Lin	26 tessera/14 diferent colours
Elbasan	35 tessera/18 diferent colours

Each of them was polished ground on successive grades of grinding paper, silicon carbide, from 250 to 4000 grit and the final colour determination of each sample was done by visually comparing the samples to a Pantone colour chart.

The microstructure of the samples were analyzed using optical microscopy. Each seample were examined under a optical microscope Kozo XJP300 with polarized and reflected light, equipped with a digital camera and under a digital microscope (Keyence, VHX-500FD) with a VH-Z20 objective (20x – 200x).

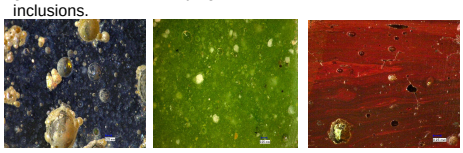
To determine the concentration of trace elements, each sample was measured with portable micro X-ray spectrometer Artax. Scanning electron microscope Quanta 200 from FEI coupled with energy dispersive spectrometer X Flash 4010 from Bruker, (SEM-EDS), was used to determine the concentrations of major elements.

Micro-Raman spectroscopy has been used to study inclusions in the glass which function as colorants and opacifiers in ancient glasses. Spectra were acquired with a Horiba XploRa Raman-Microscope managed by the software Labspec5, fitted with lasers of wavelength 532 nm, 638 nm and 785 nm.

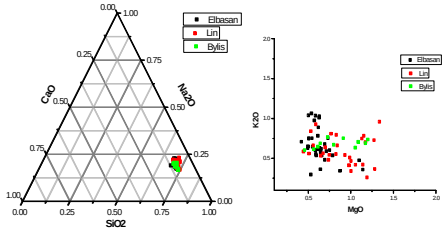
Results

Microscopy and analytical analyses

Microscopic examinations of these tesserae show a uniform glass surface with varying number of air bubbles and/or inclusions.



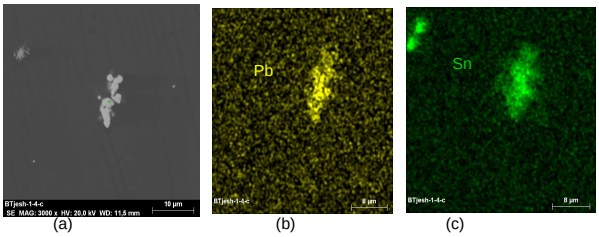
From the analyses with SEM-EDS and micro XRF results that the glass matrix of all tesseare belongs to soda-lime-silica type, which is typical for that period, [7], [8].



Ternary and binary diagram for all the glass tesserae

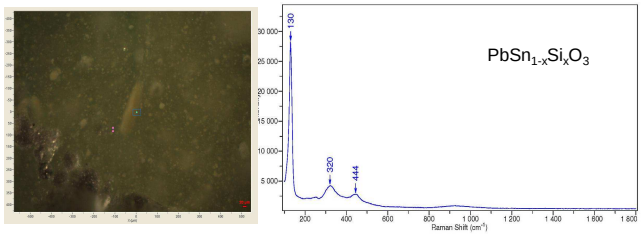
The MgO-K2O plot shows that all samples can be characterized as low magnesia and low potash, indicating a natron based glass, [9], [10] .

Colourants & opacifiers



(a) (b) (c)

Green glass tesserae from Byllis
(a)Backscattered electron photomicrograf; (b) and (c) respectively Pb and Sn elemental maps.
These particles appear to be responsible for the opaque yellowish colour in these tesserae [11],



Images and subtracted Raman spectra of yellow part, green tesserae, Bylis.
The identification of Raman signature in the yellow inclusion of the glass tesserae, gives the presence of lead tin yellow type II ($PbSn_{1-x}Si_xO_3$) [11].

Micro XRF qualitative results

Tesserae colour	Colorizing/opacifier
Transparent glass	De-colorizing **Mn** compounds
Yellow	**Pb, Sn** compounds (probably lead tin yellow), [6].
Lime green	**Fe and Pb, Sn** compounds (probably lead tin yellow) Without **Mn** , [6].
Green	**Cu and Pb, Sn** compounds (probably lead tin yellow), [6.]
Navy	**Co and Cu** compounds
Blue	**Cu** and, small amount of Pb, Sn, [4], [5].
Red	**Metallic Cu, Zn, Pb, Sn** (probably brass), [6].
Dark violet	**Mn, Fe** with small amounts of Pb
Yellow gold	**Gold leaf** between two transparent glass layers

Conclusions

All the samples are soda-lime-silica glasses, with low potash and magnesia. There is a general consensus that glass of this type was made using evaporitic sodium carbonate, commonly termed natron. Natron or low-magnesia glass is the compositional type of most Roman and Byzantine glasses, [10].

Mixture of Sn, Pb oxides along with the air bubbles are used as opacifiers. Lead -tin yellow type II is used for the yellow color.

Mn compounds are generally used for decolorizing the glass. An excess of these compounds was used to confer the dark violet color.

Iron is used to confer a light green nuance to the glass while a combination of Cu compounds and lead tin yellow are found in most of the green colored tesserae.

Cu and Co compounds were used for the different hues of the blue color.

The red color is produced by crystals of metallic copper dispersed in the glass matrix, the differences in the resulting nuances being mainly related to the dimensions of the particles.

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Acknowledgments

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