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Data Article

Dataset of chemical composition of Avar age glass beads

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ABSTRACT

Monographic processing of Avar Period (6–8th century) glass beads. Approx. 200 glass beads have been selected from 13 archaeological sites in current day Hungary as the representatives of typical Avar glass beads. The beads were analyzed with electron microprobe analyzer attached with wavelength dispersive X-ray spectrometer and/or energy dispersive X-ray spectrometer peripheries for 12–15 elements complemented with archaeological and color description. These beads provide insights primarily into the trade and interactions of the Avar population in the Carpathian Basin with other peoples. Through their analysis, we can learn about the economic systems associated with glass production and the connections between different regions. Furthermore, Avar Age glass beads offer valuable information about craftsmanship and artistic expression. Their diverse shapes, colors, and patterns showcase the skill and creativity of the artisans who made them, as well as hint at the production technology used. The purpose of data collection is to identify the raw materials and coloring agents used in bead production, detect potential chronological changes, internationally explore the identified production technology in terms of space and time, and out-

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line the Avars' trade network, and provide reference for future research. This is the first ever published database of Avar Age glass beads.

Specifications Table

Subject	Social Sciences / Archaeology Chemistry / Analytical Chemistry: Spectroscopy
Specific subject area	The subdiscipline is 'interdisciplinary' between archaeology and analytical chemistry, *archaeometry*. In archaeometry, approaches from the physical, chemical, biological, and earth sciences are used to address questions and problems providing empirical and systematic ways of collecting, analyzing, synthesizing, and interpreting data related to the inorganic and organic material record of human history.
Data format	Analyzed, Filtered
Type of data	Table, Image
Data collection	Data collection involved preparing cross-sections from samples, grinding, polishing, and vacuum vapor deposition for a thin carbon layer. Beads were cut or ground, embedded in resin, polished, and coated with carbon. Quantitative analysis of colored regions, avoiding larger inclusions, covered areas of several hundred μm^2. Densely distributed precipitates (< 1 μm) were included. Electron-microprobe analysis used a JEOL JXA-733 attached with a wavelength dispersive X-ray spectrometer (WDS; JEOL made) and/or energy dispersive X-ray spectrometer (EDS; Oxford Instruments made). Natural mineral standards were applied as reference material. Software provided by the instrument manufacturer was used.
Data source location	Archaeological sites are all located in Hungary (Europe) at the following coordinates (EPSG: 4326)

Site	LAT	LON
Budakalász-Dunapart	47.62128	19.05087
Csongrád-Felgyő-Ürmös-tanya	46.67227	20.11813
Deszk	46.21796	20.24041
Keszthely-Fenékpuszta-déli-erődfal	46.73968	17.24488
Keszthely-Fenékpuszta-Pusztaszentegyházi-dűlő	46.73968	17.24488
Szegvár-Sápoldal	46.58165	20.22664
Szekszárd-Bogyiszlói út	46.34743	18.70623
Szegvár-Oromdűlő	46.58165	20.22664
Szegvár-Szőlőkalja	46.58165	20.22664
Tiszavasvári-Petőfi-u.	47.95997	21.3697
Szentendre	47.67953	19.06686
Tiszaföldvár-Téglagyár	46.96525	20.2525
Vasasszonyfa	47.31171	16.67097

	The raw data are stored at the Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, H-1112 Budapest. Budaörsi út 45., Hungary
Data accessibility	Repository name: ARP Adatrepozitórium Data identification number: https://doi.org/10.5158/ARP/2NIV5H Direct URL to data: https://doi.org/10.5158/ARP/2NIV5H The data is licensed under a CC BY-NC-ND 4.0 DEED (https://creativecommons.org/licenses/by-nc-nd/4.0/) license.

1. Value of the Data

- The dataset provides chemical composition, color photographs of the original glass beads and of sections of glass beads from 13 archaeological sites in Hungary dated to the Avar age (6th–8th c. AD).
- This dataset consists of 348 chemical compositions (339 glass matrix and 9 inclusions) of 202 colored glass beads determined by EPMA-WDS and EPMA-EDS, and 111 color photographs.

- The dataset is a future reference for studying the trading of glass beads and glass in general between ethnic groups and peoples lived during the period of 6th–8th c. AD in the broader Carpathian region and more distant areas like the Crimea or the Caucasus where similar beads appeared.
- The dataset can be a reference for studying the history of glass making. The types of raw materials used for glass making and pigments used for coloring can be deduced from the data.
- The photograph dataset can be used for identifying the same types of glass beads in other archaeological sites.
- The rate / frequency of recycling of glass can be determined from e.g. the Sb and Mn content of glass beads that are published in the present paper. This is vital for assessing the possible origin of the raw glass.

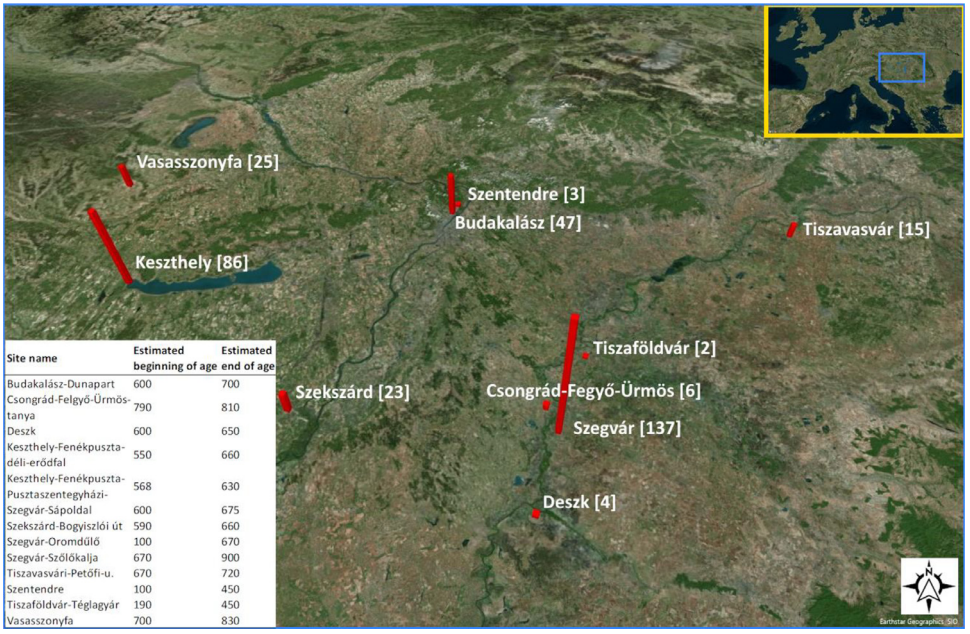
2. Background

In 567/568 AD, an oriental nomadic people of Inner Asian and Central Asian origin, known as the Avars, permanently settled in the Carpathian Basin [1]. With their occupation, the western and eastern parts of the region became part of a political and economic entity, which, for about 250 years, developed its own distinct material culture [2].

The most comprehensive understanding of Avar society, their attire, and their daily lives can be constructed based on the material remains uncovered in excavated burials. The Avars believed in an afterlife as a continuation of earthly existence, thus they equipped the deceased with worldly possessions and personal belongings. According to pagan beliefs, the deceased were often buried in elaborate attire, adorned with jewelry, and accompanied by their everyday items, tools, and weapons, reflecting their social status [3]. These artifacts also indicate that while the wealthiest individuals predominantly wore Byzantine precious metal and gemstone jewelry [4], the more prominent elites and common male members of society [5], less frequently, and their women and daughters often adorned themselves with colorful glass bead necklaces, shorter or longer, even multi-strand necklaces [6].

Along with the artifacts from the Avar period, tens of thousands of beads have found their way into Hungarian museums. The primary aim of these investigations is to enrich our knowledge of Avar-era trade relations, clothing customs related to changing fashion trends of the period, and the industrial and cultural development through the collective analysis of various types of beads and the artifacts found alongside them. Research from various archaeological periods has already proven that both individually crafted and mass-produced tiny ornaments can aid in dating within a specific era. The material culture of extinct or assimilated auxiliary peoples within the Avar Empire, as well as ethnic groups living in proximity to the Avars with whom they had close political or trade relations, can also provide valuable insights. Their knowledge can offer a more nuanced understanding of the social stratification of Avar communities, their traditional attire customs, and their changes over time. Changes in the composition of bead necklaces, the appearance or disappearance of certain types of beads, signify shifts in fashion trends. Due to the widespread use of bead necklaces, similar to contemporary costume jewelry, they vividly characterize past fashion phenomena and changes, while also aiding in the identification of traditional and local workshops. Written sources mostly remain silent about the history and lifestyle of the Avars in the Carpathian Basin [7–9].

Avar Age glass beads provide insights primarily into the trade and interactions of the Avar population in the Carpathian Basin with other people's living within or outside the Carpathian Basin. There are certain bead types which have got parallels in more distant areas like the Crimea or the Caucasus [10]. Through the archaeometric analysis of glass beads, we can learn about the economic systems associated with glass production and the connections between different regions. "Same style and different chemical composition" would mean that only the aesthetic appearance is shared by different ethnic groups, while "same style and same chemical composition" would mean trading connections, where either the raw glass or the finished prod-



Site name	Estimated beginning of age	Estimated end of age
Budakalász-Dunapart	600	700
Csongrád-Felgyő-Ürmös-tanya	790	810
Deszk	600	650
Keszthely-Fenékpuszta-déli-erődfal	550	660
Keszthely-Fenékpuszta-Pusztaszentegyházi-Szegvár-Sápoldal	568	630
Szegvár-Sápoldal	600	675
Szekszárd-Bogyiszlói út	590	660
Szegvár-Oromdűlő	100	670
Szegvár-Szőlőkalja	670	900
Tiszavasvári-Petőfi-u.	670	720
Szentendre	100	450
Tiszaföldvár-Téglagyár	190	450
Vasasszonyfa	700	830

Fig. 1. Location of the archaeological sites in the Carpathian Basin**.** The names of the archaeological sites are presented next to the red columns on the map. The numbers in brackets and the height of the columns indicate the number of beads excavated at a given site. The inset map in the top right corner shows Europe and the study area within a blue rectangle. The bottom left table indicates the estimated beginning and end of the beads' ages. Basemap from Bing Maps. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

uct was traded. Furthermore, Avar Age glass beads offer valuable information about craftsmanship and artistic expression. Their diverse shapes, colors, and patterns showcase the skill and creativity of the artisans who made them, as well as hint at the production technology used. The same color was produced by different methods through space and time during the history of glass making. By examining the materials used and the techniques applied, we can gain a deeper understanding of early medieval glassmaking technologies and the cultural preferences of the Avar people [7–17].

The motivation of compiling the dataset was to make easily accessible for the international audience the chemical data of hundreds of Avar Age glass beads which were produced throughout the recent decades by analyses as described in Section 4, and were published in journal papers [11–13], and in difficulty accessible conference proceedings [11–17] in Hungarian. Additionally, the results of analytical investigations of glass beads from the Vasasszonyfa site (Fig. 1) were still unpublished.

In order to answer the questions outlined above, we wanted to include in a unified system the previously partially and inconsistently published data, which were only under institutional care.

3. Data Description

This article describes the dataset of Avar Age glass beads collected from 13 archaeological sites across Hungary (Europe) (Fig. 1) from 81 numbered-, and one unmarked graves providing 202 Avar Age glass bead sampled. The colors vary in a wide range (more than 20 variations) e.g. blue, white, brown, green, colorless, orange, red, black, yellow, brownish-red, greenish-blue etc.

Table 1
Data description table: Variables and their detailed explanation.

Variable	Explanation
Publication	Publication(s) in which results have been reported.
Archaeological site	The place where the glass bead was unearthed.
Grave number	Number of the grave, where the bead was found.
Sample name	Name of sample prepared for instrumental analysis.
Color of measured part	The color of the area measured. It has an importance in the case of multicolor beads.
Type of analyzed part of bead	This tells if the measured area is on the body or on the ornament of a bead. Monochrome always means body of bead unornamented.
Transparency	Opaque means "not letting light through". Translucid means "allowing light to pass through scattering it", the glass has a color and some part of the light can go through the glass. Transparent means having the property of transmitting light without appreciable scattering or absorption.
Age / phase	The archaeological age of the bead determined by archaeological or scientific methods.
Estimated beginning of age	Always A.D. (CE).
Estimated end of age	Always A.D. (CE).
Type of bead if not Avar	In the case when the bead has an appearance which is characteristic for non-Avar population, e.g. for Sarmatians, in spite the fact that it was found in an Avar cemetery.
Museum	The bead belongs to the collection of this museum.
Excavation leader	The leader of the excavation when the bead was found.
Sample provided by	Person(s) who provided the bead for instrumental analysis (Surname Given name).
Analytical method	WDS = **W**avelength **D**ispersive X-ray **S**pectroscopy; EDS = **E**nergy **D**ispersive X-ray **S**pectroscopy (Oxford INCA 200). The base instrument was always a JEOL Superprobe 733 electron microprobe. All measurements are standardized. The following standards were used: orthoclase for Si & K; spessartine for Al & Mn; olivine for Fe, Mg; scapolite for Ca, Na & Cl; SnO_2 for Sn; PbSe for Pb; $CuFeS_2$ for Cu. Parameters for the measurements; WDS: accelerating voltage: 15 kV, probe current: 50 nA, area: circle of 20 micrometer (μm) diameter, time: 25 s per element; EDS: accelerating voltage: 20 kV, probe current: 5 nA, area: 25×30 μm^2, live time: 100 s.
Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, SO_3, Cl, K_2O, CaO, MnO, FeO, CuO, SnO, SnO_2, Sb_2O_3, PbO	Chemical components that make up the bead material. The iron is expressed here as FeO (as it was published) although most probably it is in the form of Fe_2O_3 in the glass.
Analytical total	The sum of the components. In the case of unaltered glass, it should be around 100 %. A number significantly less than 100 means a) the glass is altered or b) there were cavities (e.g. gas bubble) on the measured surface.
Base glass (matrix) or inclusion	This tells whether the measured area is the base glass (matrix) or an inclusion in the glass matrix. In the case of opaque glass the matrix may contain small crystalline inclusions.
Note	An important notice.
Photo documentation	Photos made of the bead itself or of the prepared (imbedded in resin and polished) sample.

The dataset [18] contains two tabulated files (.xlsx), one in English (Avar age glass beads_ENG.xlsx) and one in Hungarian (Avar age glass beads_HUN.xlsx), with the same scientific and data content. Both of these tabulated files consist of three worksheets (*description; bead_data*; and *geo_coordinates*) in one Excel workbook. The first worksheet provides a detailed description of the data and metadata variables found in the *bead_data* worksheet (description can also be found in Table 1), while the *geo_coordinates* document the LAT LON coordinates of the sites in World Geodetic System 1984 projection, European Petroleum Survey Group code: 4326.

Photo documentation (*bead_data*: column AI: *Photo documentation*) is also available for about 55 % of the samples (*bead_data*: column D). The photo documentation can be found in the 'Photodocumentation' library which contains photographs of the beads featured in the mate-

rial under examination and is related to both the English and Hungarian versions of the dataset. The files in this folder are in .pdf, .png and .jpg format.

Additionally, one folder can be found in the dataset, 'Hungarian_descriptions', which is only related to the Hungarian version in column AK: *Leírás (szöveg).* It contains archived (scanned) versions of the notes in Hungarian, which describe the origins and visual parameters and sizes of the observed beads.

4. Experimental Design, Materials and Methods

From the samples, cross-sections were prepared before the examinations. The flat-cut surfaces were subjected to grinding and polishing, followed by vacuum vapor deposition to obtain a thin carbon layer. The selected beads were cut for making possible to study the inner texture of the glass beads and to determine their chemical composition, this way avoiding any deteriorated layers on their surfaces. Subsequently, the samples were embedded in resin, polished, and finally coated with a thin vacuum-vapor-deposited carbon layer. Quantitative analysis of the beads' different colored regions, typically in areas of several hundred μm^2, was performed to avoid larger inclusions and bubbles. However, in some cases (red & white opaque glass) small (< 1 µm), densely distributed precipitates were included in the analysis.

The prepared samples underwent two types of electron-microprobe analysis: wavelength dispersive X-ray spectrometer (WDS) and/or energy dispersive X-ray spectrometer (EDS), or both, in approximately 60 %, 30 %, and 10 % of the cases, respectively. The examinations were conducted using a JEOL JXA-733 electron microprobe, and the analyses were performed with its three-wavelength dispersive X-ray spectrometer. Measurement conditions for WDS: acceleration voltage 15 kV, beam current 50 nA, beam diameter 20 µm, counting time 5×5 s. Measurement conditions for EDS: acceleration voltage 20 kV, beam current 5 nA, beam area 25×30 μm^2, counting time 100 s. Applied standards (natural mineral standards): orthoclase for Si and K; spessartine for Al and Mn; olivine for Fe and Mg; Ca, scapolite for Na, and Cl; SnO_2 for Sn; PbSe for Pb; and $CuFeS_2$for Cu.

The measured compositions (in accordance with general practice) are given in oxide weight percent (excluding chlorine); the oxidation states of variable valence elements – Mn, Fe, Cu, Pb – were not investigated. The samples were not always complete beads, and generally, the requirement was that at least half of the bead remained untouched. Multiple samples were often examined from beads of the same color or type, allowing for some generalizations and the determination of characteristics related to the same type or color of glass.

Ethics Statement

Authors confirm that we have read and followed the ethical requirements for publication in Data in Brief and that the current work does not involve human subjects, animal experiments, or any data collected from social media platforms.

CRediT Author Statement

István Fórizs: Conceptualization, Methodology, Formal analysis, Investigation, Writing, Original draft, Writing - Review & Editing. **István G. Hatvani**: Data Curation, Writing, Original draft, Visualization. **Géza Nagy**: Investigation, Software, Formal analysis. **Tóth Zoltán**: Data Curation. **Adrien Pásztor**: Conceptualization, Investigation, Funding acquisition.

Data Availability

Monographic assessment of Avar Age glass beads (Original data) (ARP Adatrepozitórium).
Monographic assessment of Avar Age glass beads (Original data) (ARP Adatrepozitórium).

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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