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Study the Chemical Composition Content of Ancient Glass Products before Weathering

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Abstract: Ancient glass preserved in a burial environment for a long time will weather, which in turn leads to changes in its chemical composition and proportion. In this paper, we analyzed the relationship between surface weathering and glass type, ornamentation and color, and used the statistical principles related to statistics to draw statistical graphs to find out the statistical pattern of the presence or absence of chemical composition content on the surface of the artifact samples; established a regression prediction model and used MATLAB software to calculate and predict the chemical composition content of this batch of ancient glass before weathering; solved the problem of dividing the subclasses of two glass types, high potassium glass, and lead-barium glass, and used K-mean clustering method and spectral clustering method for cluster analysis, determined the chemical composition indexes for the division, and the approximate range of values for the division, derived specific division methods and results, and finally analyzed the reasonableness and sensitivity of the results.

1. Introduction

The original glass goods were born from the people living in West Asia and Egypt and other regions to make glass into beautiful bead-shaped jewelry, due to the inflow of this batch of glass goods, the level of our ancient glass-making process has been improved to a certain extent, although the chemical composition of our ancient glass and foreign glass products are different, the appearance has been more similar.

The main component of glass is silica, to reduce its melting temperature to reduce the cost of glass production, a flux should be used in refining, in addition, we also need to use limestone as a stabilizer, the added limestone will be converted into calcium oxide (CaO) during the refining process. Different fluxes have different main chemical compositions. For example, lead ore is used as a flux when firing lead-barium glass, and the product contains more lead oxide (PbO) and barium oxide (BaO), and the flux usually added for firing potassium glass is a substance with high potassium content such as grass ash. Ancient glass preserved for a long time in a burial environment will weather, which in turn leads to changes in its chemical composition and ratio.

In this paper, we investigate the relationship between weathering and glass type, decoration and color on the surface of glass relics, and then combine the glass types to find the statistical law of weathering chemical composition content on the surface of glass relics, and predict the chemical composition content before weathering; find the classification law of high potassium glass and lead-barium glass, classify the subclasses according to the chemical composition of each class respectively, and analyze the reasonableness and sensitivity of the results

2. Multiple regression model

First, only the data of surface weathered artifacts were selected for analysis in this paper. On this basis, this paper ensures the principle of a single variable, the statistical analysis of glass type, decoration, and color of the weathered artifacts' glass, and draws a fan-shaped statistical graph to visualize the relationship between the surface weathering of the glass artifacts and their glass type, decoration, and color. Then combined with the glass type to find out the statistical pattern of the content of the surface weathering chemical composition of the artifact samples. According to the classification of high potassium glass and lead-barium glass, statistical analysis was conducted separately, and a sector statistical chart was drawn to highlight the statistical pattern of weathering chemical content; based on the weathering point detection data, a regression prediction model was established to predict the chemical composition content of this batch of cultural relics before the weathering of glass. Cluster analysis using the spectral clustering method and the K-mean clustering method was performed to subclassify the chemical composition content of high potassium glass and lead-barium glass. The spectral clustering method can select suitable chemical composition indicators, and the K-mean clustering method can classify the data on this basis.

First, a multiple regression model was established [1], as shown in equation (1).

$$\begin{cases} y = \beta_0 + \beta_1 x_1 + ... + \beta_m x_m + \varepsilon \\ \varepsilon \sim N(0, \sigma^2) \end{cases} \tag{1}$$

Where: β_0, $\beta_1 \ldots \beta_m$, σ^2 are all unknown parameters independent of x_1, x_2...xm independent of the unknown pparameterswwheree β_0 , $\beta_1 \ldots$ β_m, σ^2 can also be referred to as regression coefficients, expressed as equation (2):

$$\begin{cases} Y = X\beta + \varepsilon \\ \varepsilon \sim N(0, \sigma^2 E_n) \end{cases} \tag{2}$$

Where E_n is a unit matrix of order n. In this paper, the data in Form 2 are substituted as matrix E_n.

Then, parameter estimation and statistical analysis are performed, followed by hypothesis testing of the regression model, followed by hypothesis testing and interval estimation of the regression coefficients, and finally, prediction using the regression model [2].

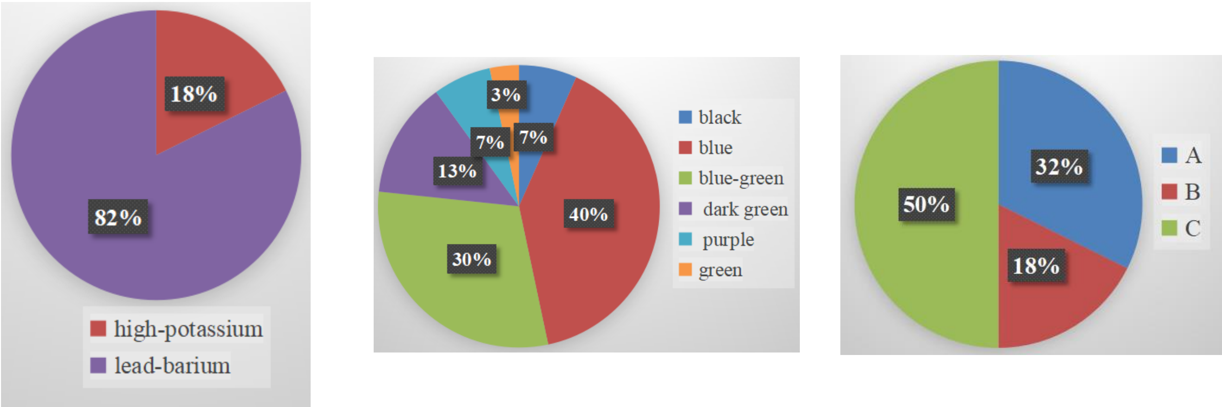
Cluster analysis, also known as cluster analysis, is a multivariate statistical analysis method for the quantitative classification of multiple samples (or indicators) [3-4]. Clustering is a process of dividing a data set into groups (classes or classes (clusters) and making data objects within the same group have a high degree of similarity; while data objects in different groups are dissimilar. Similarity or dissimilarity is determined based on the values taken for the data description attributes and is usually expressed using the distance between the data objects. Cluster analysis is particularly suitable for exploring the interrelationships between samples to make a preliminary evaluation of a sample structure.

In this paper, cluster analysis is performed using spectral clustering and K-mean clustering methods to classify them. First, the K-average clustering algorithm is applied and the mean squared difference is chosen as the convergence criterion function. Between chemical components

$$E = \sum_{n=1}^{k} \sum_{p \in C_i} |p - m_i|^2 \tag{3}$$

In Eq. 3, the sum of the mean squared differences of all objects in the *E* database; *p* is a point in the space representing the object; mi is the mean value of the cluster C_i.

3. Results and Discussion



(a) Percentage of different types of weathered glass

(b) Percentage of different color weathered glass

(c) Percentage of weathered glass with different decorations

Figure 1: Percentage of weathered glass

As can be seen from Figure 1, the batch of an ancient glass of the type of lead-barium glass weathered in larger quantities, and it is inferred that lead-barium glass is easier to weather. There are more light blue and blue-green glass and less dark green, black and purple glass in the ancient glass, and it is inferred that light blue and blue-green glass are easier to weather, and dark green, black and purple glass is less likely to weather. There are more weathered glasses with C motifs and fewer A and B types of weathered glasses, and it can be inferred that ancient glass artifacts with C motifs are more prone to weathering.

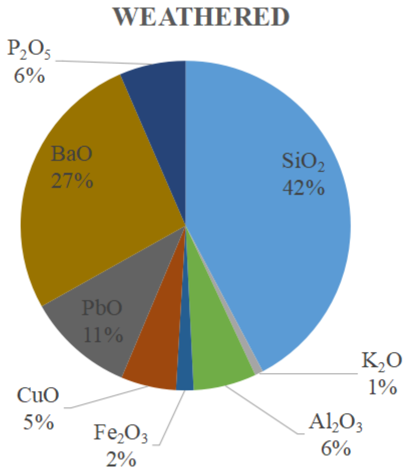


Figure 2: Chemical composition of unweathered high-potassium glass as a percentage

By analyzing Figure 2, it can be learned that the unweathered high-potassium artifact glass contains more silicon dioxide (SiO2), potassium oxide (K2O), calcium oxide (CaO), aluminum oxide (Al2O3), and lessfewerer substances. Since the main component of the glass is silicon dioxide (SiO2), it can be inferred that the high potassium relic glass containing potassium oxide (K2O), calcium oxide (CaO), and aluminum oxide (Al2O3) is more difficult to weather.

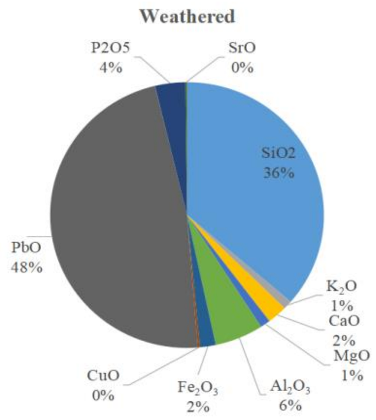


Figure 3: Chemical composition of weathered high-potassium glass as a percentage

By analyzing Figure 3, it can be learned that the unweathered high-potassium heritage glass contains more silicon dioxide (SiO2), copper oxide (CuO), and aluminum oxide (Al2O3) and fewer other substances, and since the main component of the glass is silicon dioxide (SiO2), it can be inferred that the high-potassium heritage glass containing copper oxide (CuO) and aluminum oxide (Al2O3) is more easily weathered.

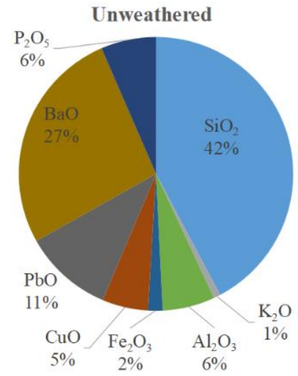


Figure 4: Chemical composition of unweathered lead-barium glass as a percentage

By analyzing Figure 4, we can learn that the unweathered lead-barium glass contains more silicon dioxide (SiO2), barium oxide (BaO), and lead oxide (PbO) and fewer other substances, and we can infer that the lead-barium heritage glass containing barium oxide (BaO) and lead oxide (PbO) is more difficult to weather.

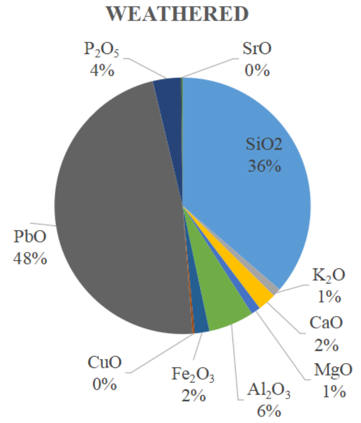


Figure 5: Chemical composition of weathered lead-barium glass as a percentage

By analyzing Figure 5, it can be learned that the weathered lead-barium glass contains more lead oxide (PbO), silicon dioxide (SiO2), and aluminum oxide (Al2O3) and fewer other substances, and since the main component of the glass is silicon dioxide (SiO2), it can be inferred that the lead-zinc glass containing lead oxide (PbO) and aluminum oxide (Al2O3) is easier to weather.

The clustering analysis was solved by MATLAB for the two classes separately, and the clustering process of the K-average clustering method algorithm is shown in Fig. 6 and Fig. 7 below, and the spectral clustering method was used for the spectral clustering diagram shown in Fig. 8 and Fig. 9 below.

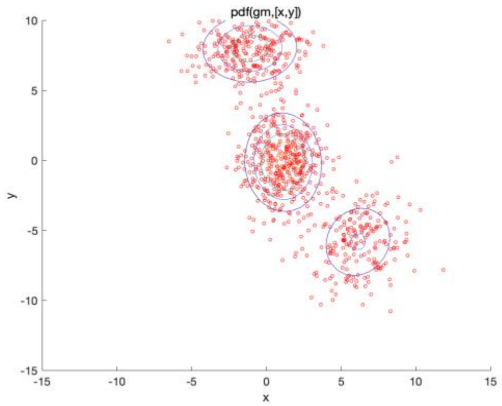


Figure 6: K-mean clustering high potassium heritage glass analysis

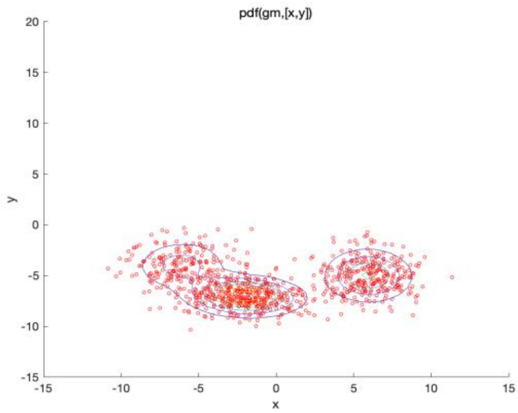


Figure 7: K-mean clustering lead-barium heritage glass analysis chart

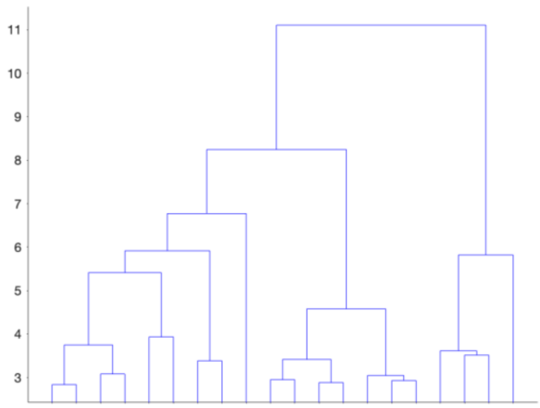


Figure 8: High potassium heritage glass spectrum clustering map

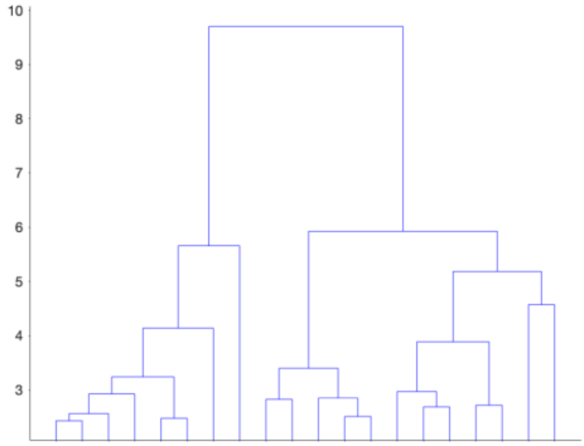


Figure 9: Cluster diagram of lead-barium heritage glass spectrum

In figure 6 we can see that the high potassium heritage glass can be clustered into three categories.

Subclassification of lead-barium glass: The classification indexes selected through cluster analysis are calcium oxide (CaO), aluminum oxide (Al2O3), lead oxide (PbO), barium oxide (BaO), and strontium oxide (SrO), as shown in Table 1 below.

Table 1: Subcategories of lead barium glass

	Class 1	Class 2	Class 3
CaO	<=0.64	0.64~3.19	>=3.19
Al_2O_3	<=1.6	1.6~5	>=5
PbO	<=19.76	19.76~45.1	>=45.1
BaO	<=5.22	5.22~14.2	>=14.2
Sri	<=0.19	0.19~0.48	>=0.48

Subclassification of high potassium glass to lead-barium glass: The classification indexes selected were potassium oxide (K2O), calcium oxide (CaO), aluminum oxide (Al2O3), copper oxide (CuO), and phosphorus pentoxide (P2O5) as shown in Table 2 below, derived by cluster analysis.

Table 2: Division of high potassium glass subclasses

	Class 1	Class 2	Class 3
K_2O	<=0.92	0.92~9.67	>=9.67
CaO	<=0.21	0.21~7.12	>=7.12
Al_2O_3	<=2.51	2.51~6.18	>=6.18
CuO	<=1.07	1.07~2.51	>=2.51
P_2O_5	<=0.21	0.21~0.94	>=0.94

The clustering analysis can be built on data without class markers; the K-average clustering method turns out to be simple and easy to handle a large amount of data [5]; the K-average clustering method is only applicable to occasions when the clustering means is meaningful and is sensitive to noise and isolated point data; the K-average clustering method can be combined with the genealogical clustering method, and the model in this paper can be extended to related fields such as the study of ancient cultural relics.

4. Conclusion

The main conclusions of this paper are as follows.

(1) Ancient glass with lead-barium glass is more prone to weathering; light blue and blue-green

glass are more prone to weathering, and dark green, black and purple glass is less prone to weathering. Ancient glass artifacts with C motifs are more prone to weathering.

(2) High potassium artifact glass containing potassium oxide (K2O), calcium oxide (CaO), and aluminum oxide (Al2O3) is more difficult to weather; high potassium artifact glass containing copper oxide (CuO) and aluminum oxide (Al2O3) is easier to weather; lead-barium artifact glass containing barium oxide (BaO) and lead oxide (PbO) is more difficult to weather.

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